EFFECT OF MANAGEMENT PRACTICE AND CROPPING INTENSITY ON NUTRITIONAL STATUS OF LOW GANGES RIVER FLOODPLAIN SOILS

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IN
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DEDICATED
TO
MY DEPARTED PARENTS

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A DISSERTATION
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Declaration

I do hereby declare that the submitted thesis titled "**Effect of Management Practice and Cropping Intensity on Nutritional Status of Low Ganges River Floodplain Soils**" has been composed by me and all the works presented herein are of my own experimental findings. I further declare that this work has not been submitted anywhere for any academic degree, prize or scholarship and not published anywhere.

Date:

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Certificate

This is to certify that the research work presented in this dissertation, titled "**Effect of Management Practice and Cropping Intensity on Nutritional Status of Low Ganges River Floodplain Soils**" has been performed by **Mr. Md. Thouhidul Islam** in the experimental fields of Gopalganj district and laboratory of the Department of Soil, Water and Environment, University of Dhaka, under my guidance and supervision. The part of this dissertation has not been submitted elsewhere for any degree or diploma. It is also certified that the work presented herein is original and suitable for submission for the award of Ph.D. degree.

Prof. Dr. Sirajul Hoque

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ABSTRACT

Field experiments were conducted at the farmers' field of Lower Ganges River Floodplain (AEZ12) in Kashiani upazila of Gopalganj District during the period of 2013-2015 with an objective to find out the effect of crop production on the nutritional status of soils as well as the nutrient balances due to the nutrient management. Two cropping patterns i.e. Jute - T. aman – Mustard in Sara series and Jute - T. aman - Lentil in Gopalpur series were practiced to maintain croppingintensity. The field experiments were laid out in randomized complete block design (RCBD) having eleven treatments composed of chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake with three replications. Each plot size was 5m x 4m. The integrated use of chemical fertilizers and manures resulted considerable improvement of the physical and chemical properties of soils.

The treatments had significant effect on bulk density and total porosity in Gopalpur series soil. The lowest bulk densities of 1.17 and 1.20 g cm^{-3} were recorded with 75% of fertilizers applied by farmers + 75% recommended S&B + cow dung treatment in soils of Sara and Gopalpur series, respectively. The hydraulic conductivity and soil moisture content were also significantly higher with 75% of recommended fertilizer + cow dung treated plots in soils of both Sara and Gopalpur series. The significantly higher organic matter content of 1.71% and CEC of 28.13cmol kg^{-1} soil were obtained with 75% of recommended fertilizers + cow dung treatment in both soil series. But, the 75% of recommended fertilizers + oilcake treatmentprovided significantly maximum total N contents of 0.123 and 0.148% and available S contents of 35.04 and 41.70 µg g^{-1}in Sara and Gopalpur series, respectively. The application of 75% of farmers' practice + 75% of recommended S&B+ poultry manure and 75% of recommended fertilizers + cow dungtreatmentsincreased the available P and K contents to the highest level. The soil analysis based treatment produced significantly higher available Zn content (1.183 µg g^{-1}) in Sara series. With some exceptions, the changes in available Na, Ca, Mg, Fe, Mn, B and Cu contents in both soils were found non-significant due to the application of different treatments. The results revealed that the combined application of chemical fertilizers and manures resulted in remarkable improvement in soil properties by increasing organic matter and nutrient contents in both calcareous soils. The soils of

sixteen different locations showed considerable variations in nutrient contents and arefree from heavy metal contaminations.

The significantly higher yields of jute fibre of 4.98 t ha^{-1},jute stick with barkof 14.55 t ha^{-1}, rice grain of 4.57 t ha^{-1}, rice straw of 6.22 t ha^{-1}, mustard grain of 1.45 t ha^{-1} and stover of 4.52 t ha^{-1}in Sara series, and yields of jute fibre of 5.01 t ha^{-1}, jute stick with barkof 14.38 t ha^{-1} and rice grain of 4.54 t ha^{-1}in soils of Gopalpur series were found with 75% of recommended fertilizers + oilcake treatment. While the 75% of recommended fertilizers +poultry manure treatment provided significantly higher yields of rice straw of 4.52 t ha^{-1}, lentil grain of 1.74 t ha^{-1} and lentil stover of 1.73 t ha^{-1} in soils of Gopalpur series. The nutrient contents and uptake were significantly higher with the application of 75% of recommended fertilizers + oilcake in Sara and Gopalpur series, which were followed by 75% of recommended fertilizers+poultry manure treatment and then 75% of recommended fertilizers+cow dung treatment. With a few exceptions, the treatment consists of75% of recommended fertilizers + oilcake resulted in considerable higher nutrient contentsand uptake in the examined crops among the three manures based treatments.The results shows that the chemical fertilizers+oilcaketreatment was more suitablethan the other treatments to supply sufficient nutrients for the crops under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns.

Thus, the apparent balances for N, P, S, Zn and B were found positive in case of combined application of chemical fertilizers and organic manures (cow dung, poultry manure and oilcake) except K balance, while only chemical fertilizers based treatments and control showed negative balances. The above results revealed that the nutrient management through theapplication of 75% of recommended fertilizers +oilcaketreatment resulted the higher nutritional status and maintained nutrient balancesof soils in AEZ 12 than that of chemical fertilizers alone (fertilizers applied by farmers or recommended fertilizers by BARC or soil test based treatment) or in combination with cow dung and poultry manure treatments. The application of 75% of recommended fertilizers +2 t ha^{-1}oilcakecould be recommended forthe introduced cropping patterns i.e. Jute - T. aman - Mustard and Jute - T. aman - Lentil instead of two crops based cropping patterns in AEZ 12 for sustainable higher yield in highland and medium highland soils of Sara and Gopalpur series, respectively.

LIST OF ABBREVIATIONS

AEZ	Agro-ecological Zone
ANOVA	Analysis of Variance
B. aman	Broadcasted aman
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCR	Benefit cost ratio
BINA	Bangladesh Institute of Nuclear Agriculture
BJRI	Bangladesh Jute Research Institute
BRRI	Bangladesh Rice Research Institute
C/N	Carbon to Nitrogen ratio
CD	Cow dung
CEC	Cation Exchange Capacity
CF	Chemical fertilizer
CON	Control
CRI	Crop Residue Incorporation
DAE	Department of Agricultural Extension
DAS	Days after sowing
DMRT	Duncan's Multiple Range Test
DTPA	Diethylenetriaminepentaacetic acid
FAO	Food and Agricultural Organization
FC	Field Capacity
FYM	Farm Yard Manure
GLM	Green Leaf Manure
GM	Green Manure
HYG	High Yield Goal
IPNS	Integrated Plant Nutrition System
IRRI	International Rice Research Institute
LSD	Least Significance Difference
MP	Muriate of Potash

NPK	Nitrogen Phosphorus Potassium
NU	Nutrient uptake
OC	Oilcake
OFRD	On Farm Research Division
OM	Organic Manure
PB	Phosphatic Biofertilizer
PM	Poultry Manure
PSA	Particle Size Analysis
PWP	Permanent Wilting Point
RCBD	Randomized Complete Block Design
RD	Recommended Dose
RDN	Recommended Dose of Nitrogen
REY	Rice Equivalent Yield
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SRDI	Soil Resource Development Institute
STB	Soil Test Basis
T. aman	Transplanted aman
T. aus	Transplanted aus
TSP	Triple Super Phosphate
UNDP	United Nations Development Programs
UNESCO	United Nations Educational, Scientific and Cultural Organization
USDA	United States Department of Agriculture
^{o}C	Degree Celcius
ppm	Parts per million
$\mu g\ g^{-1}$	Microgram per gram
$g\ cm^{-3}$	Gram per cubic centimeter
$mm\ h^{-1}$	Millimeter per hour
$t\ ha^{-1}$	Ton per hectare
$kg\ ha^{-1}$	Kilogram per hectare
$kg\ ha^{-1}yr^{-1}$	Kilogram per hectare per year
kg	Kilogram

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CHAPTER 1
INTRODUCTION

Bangladesh is an agro-based country. More than 65.72% people in the rural areas directly or indirectly are involved in agriculture. Agriculture plays a vital role on the economy of Bangladesh. As of December 2015, it employs 47% of the total labor force and comprises 16% of the country's GDP.The country is densely populated (1124 per sq. km.) withan area of 1,47,570 sq. km and the population is about 169 million (BBS, 2015). The total land area of Bangladesh is about 14.3 million ha, of which about 59.8% is available for cultivation(BBS, 2016).In Bangladesh, only nine crops- rice (73.94%), wheat (4.45%), jute (3.91%), rape and mustard (3.08%), lentil (1.54%), chicklling vetch (1.25%), potato (1.13%), sugarcane (1.12%), and chilli (1.05%) are grown on 1 percent or more of the crop acreage and may be considered as major crops. Rice dominates the cropping pattern throughout Bangladesh (Banglapedia, 2015).

The crop sector of Bangladesh agriculture must bear the responsibility, above all else, of producing enough food to meet the requirements of the country's ever-growing population. The pressing need is to achieve substantially higher crop yield than the existing yield levels from the limited land resources on a sustainable basis. The food production has increased due to the adaptation of modern technologies including introduction of high yielding varieties (HYV), increased use of chemical fertilizers, expansion of irrigated area and increasing cropping intensity (Bhuiyan*et al.*, 2002). On an average, the farmers of Bangladesh use 190 kg nutrients (149 kg N, 16 kg P, 18 kg K and others 7 kg) $ha^{-1}yr^{-1}$, while the estimated removal is around 280-350 kg $ha^{-1}yr^{-1}$ (Islam, 2008). The introduction of HYV and launching of intensive cropping, rapid depletion of soil nutrient contents has been observed almost all over the country (Kafiluddin and Islam, 2008).Intensive agriculture with very high nutrient turnover in soil-plant system coupled with low and imbalanced fertilizer use have resulted in deterioration of native soil fertility and created a serious threat to long-term sustainability of crop production (Anonymous, 2009).

Horizontal increase in production is not possible due to limited cultivable land area. Now, it is imperative to go with the vertical increasing of production. This is possible only by increasing cropping intensity. Multiple cropping is the way to increase cropping intensity. Sustainable crop production in Bangladesh through improvement of cropping intensity is regarded as increasingly important in national issues. In order to produce more food within a limited area, the most important options are to increase the production efficiency of the individual crop by using optimum management practices and to increase the cropping intensity producing three or more crops over the same piece of land in a year (OFRD, 2014).

Soil fertility and plant nutrition are two closely related subjects that emphasize the forms and availability of nutrients in soils. Without maintaining soil fertility, one cannot talk about increment of agricultural production in feeding the alarmingly increasing population. Therefore, to get optimum, sustained-long lasting and self-sufficient crop production, soil fertility has to be maintained.The combined use of chemical fertilizers and organic manure can be a measure to maintain sustainable soil fertility in Bangladesh where increasing organic matter content to a high level is possible (Hoque, 2009).Suitable crops need to be incorporated for developing new cropping system for increasing cropping intensity. More nutrients will be required for the new crops under cropping system that they absorb from the soil. This will exert pressure on the nutritional status of the soil which needs to replenish through nutrient management (Mian and Eaqub, 1980).

A crop production system with high-yield targets cannot be sustainable unless nutrient inputs to soil are at least balanced against nutrient removal by crops (Bhuiyan, 1991). The removal of nutrients by crops making the nutrient balance more negative and thereby depleting the substantial nutrient reserve in the soil. This negative nutrient balances and decline in soil available nutrients may cause yield decline for main crops and cropping patterns, especially if this remains unabated (Rijpma and Islam, 2011). The crops under an intensive cropping system require both adequate nutrient supplies to growing crops as well as improvements to the soil's nutrient status (De-ren and Wan-fang, 1998).

Bangladesh has been divided into 30 Agro-ecological Regions based on physiography, inundation, land types, soils, and agro-climate (UNDP-FAO, 1988; Islam *et al.*, 2003). Lower Ganges River Floodplain (AEZ-12) is one of them which comprises the eastern half of the Ganges river floodplain having predominantly developed soils of calcareous nature. Lower Ganges River Floodplain, the twelfth AEZ of Bangladesh, occupies an area of 7,968 km^2. It has meander floodplain landscape with greater relief differences between ridge and basins and mainly deeply flooded by rainwater (Rahman *et al.*, 2014). The present study was carried out in Kashianiupazila which is situated in Lower Ganges River Floodplain area.

It is well agreed that depleted soil fertility is the major constraint to higher crop production and indeed, the yield of several crops are declining in some soils (Bhuiyan, 1991). The general fertility level of the soils of Kashianiupazilais medium. The organic matter content in soils varied from low to medium level and its supply in soil is one of the major constraints to the agriculture. Because of low level of OM, the nitrogen status of these soils is substantially low and available phosphorus is also very low. Potassium is moderately deficient in the soils of Kashianiupazila. About 70-80% of the soils are deficient in sulphur. The data indicate a widespread zinc and boron deficiency in these soils (SRDI, 2002). The depletion of soil fertility in this area is mainly attributed to improper use of fertilizers and pesticides to boost up the agricultural production.

Information on the effect of organic manures viz. cow dung, poultry manure and oilcake in combination with chemical fertilizers for a specific cropping pattern underLower Ganges River Floodplain (AEZ-12) area in not adequate. Very few research works have been conducted in calcareous soils of Lower Ganges River Floodplain (AEZ-12) area. Keeping in view the above facts, the present investigation was carried out to know the impact of cow dung, poultry manure and oilcake in combination withsynthetic fertilizers and intensive cropping on the nutrient balanceunder a specific cropping system.

Objectives of the Study

- Identification of the nutrient status of soils under present land use conditions, i.e., Jute-T.aman – Mustard and Jute- T.aman - Pulse through random soil sampling and analyzing the samples for optimization of fertilizer recommendations based on soil test values.
- Investigation of the soil physical parameters such as bulk density, particle density, porosity, and hydraulic conductivity of soil samples of randomly selected representative number of samples.
- Field experiments will be conducted to find out the effectiveness of chemical fertilizers or organic manures alone or in combinations on crop yields and on soil

physical and chemical properties using two cropping patterns under flooded and non-flooded conditions for two years.

- Estimation of the balance between agricultural input and output of extensively followed cropping patterns under farmers' field condition and in the experimental areas will be done.

Structure of the Study

The study is composed of six chapters. **Chapter One** gives an overview of the background, statement of the problem, significance of the study, research objectives and structure of the thesis. **Chapter Two** has dealt with the review of the existing literature on the effect of nutrient management practices and intensive cropping on soil properties, yield, nutrient uptake and nutrient balance.**Chapter Three** deals with research materials and methods that include study area, climate and weather conditions, physiography, drainage, agro ecological zone, soil series, soil characteristics, cropping history of the experimental field, cropping season and pattern, test cropping patterns and crops, experimental details, cultural operation, plant sampling procedures, soil sampling procedure, preparation of collected samples, methods for soil and plant analysis, methods for plant analysis, nutrient uptake, nutrient balances and statistical analysis. **Chapter Four** has dealt with the results and discussionexplained extensively covering soil and plant analytical data. **Chapter Five** deals with the summary of the research activities. **Chapter Six** deals with the conclusion, recommendations and future work. **Chapter Seven**concludes with references.

CHAPTER 2
LITERATURE REVIEW

A review of literature provides information on the published available research. A better understanding of the nutrient management practices by applying chemical fertilizers and manures and cropping pattern will facilitate the development of suitable soil management practices for improving soil fertility and crop production. This chapter presents the available information regarding the effect of nutrient management and intensive cropping on soil fertility status.

2.1. Soil Management Practices

Soil management practices concern all operations, practices, and treatments use to protect soil and enhance its performance. It influences soil organic matter content and is most important with respect to soil quality; because soil organic matter was the component that showed the greatest decline when virgin prairie was first broken for cultivation (Bauer and Black, 1981). Soil organic matter continues to decline more rapidly with cropping systems involving fallow periods than with continuous cropping (Unger, 1982). As a result of these types of observations, Boyle *et al.* (1989) stressed the need for more emphasis on soil organic matter and suggested that returning carbon to the soil may be “a necessary expense that insures a sustainable harvest”. The uses of management strategies that add or maintain soil carbon, therefore, appear to be needed to improve the quality of our soil resources (Karlen *et al.*, 1992).

Soil management is an integral part of land management and may focus on differences in soil types and soil characteristics to define specific interventions that are aimed to enhance the soil quality for the land use selected. Specific soil management practices are needed to protect and conserve the soil resources. Specific interventions also exist to enhance the carbon content in soils in order to mitigate land degradation. Furthermore, some practices and treatments that involve other sustainable soil management tools can benefit the soil (FAO, 2016). Soil management practices improve soil health and increase productivity and profitability immediately and into the future. A fully functioning soil produces the maximum amount of products at the least cost. Maximizing soil health is essential to maximizing profitability (USDA, 2016).

Nutrition is the universal requirement of all living organisms. An outstanding feature of life is the capability of living cells to take up substances from the environment and use them for the synthesis of their own cellular components or as an energy source. Soils provide almost all the nutrients to plants exclusively of inorganic forms. The uptake of the nutrients by the plants is not a straightforward process, rather many factors are intimately associated with it. Most interactive processes among the chemical species and also between chemical species and soil constituents take place that influence the uptake pattern of nutrients by crops. Ecosystem is thus vital for the uptake of nutrients and their subsequent metabolism in plants (Islam, 2001).

Nutrient management, a tool of soil management practices, is the process of managing the amount, source, timing, and method of nutrient application with the goal of optimizing farm productivity while minimizing nutrient losses that could create environmental problems. It includes developing nutrient budgets that consist of knowing the amounts of nutrients present in the soil, determining the amount of nutrients needed by the crop, accounting for all the potential sources of nutrients, and then applying manures, composts, irrigation water, or inorganic fertilizers to meet the nutrient need of the crop. It also uses site management practices to increase or maintain soil quality to reduce the potential for erosion and nutrient transport into surface water or nutrient leaching into groundwater. Soil quality is an important component of nutrient management because it affects nutrient retention and water movement through the soil (Soil Quality, 2016). Soil management practices have recently changed dramatically including an increased use in synthetic fertilizers and pesticides to help crop yields. However, some studies have suggested that the excessive use of these agrochemicals may actually increase pest problems in the long run (Altieri and Nicholls, 2003).

2.1.1. Effect of Management Practices and Intensive Croppingon Physical Properties of Soil

The physical properties of soil such as bulk density, particle density, total porosity, moisture content and hydraulic conductivity are the dominant factors affecting the use of a soil for crop production. These properties of soil determine the availability of water into or through soils, and the case of root penetration (Donahue *et al.*, 1983). Both long-term and short-term organic amendments can play a vital role in changing some soil physical properties of soil. In a long-term experiment of 31 cycles of maize - wheat -

cowpea (fodder), Hatik *et al.* (2006) in India observed that the application of balanced mineral fertilizers in combination with organic manure sustained a better soil physical environment and higher crop productivity under intensive cultivation. In another experiment conducted by Mathew and Nair (1997) at Kerala, India, showed that application of cattle manure singly or in combination with NPK fertilizer improved the physical environments of the soil and concluded that the balanced application of organic manures in combination with chemical fertilizer was vital for the maintenance of soil health and productivity.

2.1.1.1. Effect on Bulk Density and Particle Density

White (1997) stated that values of bulk density ranges from < 1 g cm^{-3} for soils high in OM, 1.0 to 1.4 g cm^{-3} for well-aggregated loamy soils and 1.2 to 1.8 g cm^{-3} for sands and compacted horizons in clay soils. Bulk density normally decreases as mineral soils become finer in texture. Soils having low and high bulk density exhibit favorable and poor physical conditions, respectively. Bulk densities of soil horizons are inversely related to the amount of pore space and soil OM (Brady and Weil, 2002; Gupta, 2004). Any factor that influences soil pore space will also affect the bulk density. For instance, intensive cultivation increases bulk density resulting in reduction of total porosity.

For better plant growth, bulk density should be low about 1.4 g cm^{-3} for clays and 1.6 g cm^{-3} for sands. However, the average bulk density of cultivated loam soil is approximately 1.1 - 1.4 g cm^{-3} (Donahue *et al.*, 1983). Ghuman and Sur (2006) in a manuring experiment on wheat in India obtained the lowest bulk density (1.33 g cm^{-3}) in the green manured plots than the FYM treated plots (1.33 – 1.4 g cm^{-3}) and control plots (1.43 g cm^{-3}) which was due to the increased organic carbon content in the manured plots. Shirani *et al.* (2002) also reported a significant reduction in the surface layer bulk density of the manured fields.

Khan *et al.* (2007) in an experiment studied the effects of tillage and dairy manure on soil fertility and corn yields and reported that tillage and dairy manure had significantly reduced the bulk density of soil. In a 10-years long experiment, Bellakki *et al.* (1998) found bulk density of 1.46 g cm^{-3} in the control plots, and 1.36 and 1.31 g cm^{-3} in the plots where cow dung and rice straw were applied, respectively. Selvi *et al.* (2005) in a long-term study for 25 years in India reported that bulk density decreased from 1.44 g cm^{-3} to 1.30 g cm^{-3} significantly under NPK+FYM treated plots due to higher organic carbon, more pore space, and good soil aggregation. Hatik *et al.* (2006) found that the NPK+FYM treatment significantly reduced bulk density of the soil at 0-30 cm depth. The mean particle density of most mineral soils is about 2.60 to 2.75 g/cm^3, but the presence of iron oxide and heavy minerals increases the average value of particle density and the presence of organic matter lowers it (Hillel, 1980).

2.1.1.2. Effect on Total Porosity

The total porosity of soils usually lies between 30% and 70%. In soils with the same particle density, the lower the bulk density, the higher is the percent total porosity. As soil particles vary in size and shape, pore spaces also vary in size, shape and direction (Foth, 1990). Generally, intensive cultivation causes soil compaction and degradation of soil properties including porosity (Ike and Aremu, 1992). Fertile soils with ideal conditions for most agricultural crops have sufficient pore space, more or less equally divided between large (macro) and small (micro) pores. The decreasing OM and increasing in clay that occur with depth in many soil profiles are associated with a shift from macro-pores to micro-pores (Brady and Weil, 2002).

Selvi *et al.* (2005) in a long-term study for 25 years in India reported that combined application of NPK and FYM resulted in significantly higher porosity (54.9%) over control (50.2%). Addition of manure compost increased the porosity in the amended soil in Hong Kong (Wong *et al.*, 2001). Bellakki *et al.* (1998) conducted an experiment in India for a period of 10 years and found that rice straw incorporation either to meet 50 per cent or 25 per cent N along with fertilizers increased the porosity of soil. Mathew and Nair (1997) recorded comparatively higher values for pore space with the application of cattle manure in India.

2.1.1.3. Effect on Hydraulic Conductivity

Organic amendments can largely influence water transmission characteristics of soil. In New Zealand, Haynes and Naidu (1998) found that addition of organic manures had resulted in increased hydraulic conductivity. In a long term experiment for ten years at Agricultural Research Station, Siruguppa, India, rice straw incorporation either to meet 50 per cent or 25 per cent N along with fertilizers increased the hydraulic conductivity of soil (Bellakki *et al.*, 1998). Analysis of soil from the permanent manurial plots in Tamil Nadu, India showed that the clay content had a negative influence with respect to hydraulic conductivity and water infiltration (Vennila and Muthuvel, 1998). Khan *et al.*

(2007) reported that tillage and dairy manure had significantly improved the hydraulic conductivity.

2.1.1.4. Effect on Soil Moisture Content

Many researches indicated that fertilization significantly influenced soil water content, because fertilization stimulates plant growth and thus plant's use of soil water and its distributions (Ritchie and Johnson, 1990). Ouattara *et al.* (2006) reported that organic matter input significantly improved soil water content. He also noted that organic composts had different effects on the soil moisture in sandy loam and clay soils. All composts at high rates showed a positive impact on the soil water content, and the effect was significantly related to the amount of organic matter added (Gagnon *et al.*, 1998). The plant available soil water is held within a potential between field capacity (FC) and permanent wilting point (PWP). Available soil water content is greatly influenced by soil OM content, texture, mineralogy and soil morphology (Landon, 1991).

Sarker *et al.* (2012) carried out an experiment during the aman season of 2008 to study the effect of tillage intensity, fertilizer and manure on the root mass density, soil properties and their correlation on rice yield (BRRI dhan41). The maximum soil moisture content and air filled porosity were obtained in P_3FM_1(three passing (P_3) of a power tiller and 50% of N plus rest of recommended dose of fertilizers + cow dung @ 5 t ha^{-1}) treatment, whereas P_1FM_0(one passing (P_1) of a power tiller and recommended dose of fertilizers) demonstrated the lowest soil moisture content. The maximum (8.09 mg cm^{-3}) and minimum (1.63 mg cm^{-3}) root mass densities were observed in P_3 (10 cm depth) and P_1 (10 - 20 cm depth) treatments, respectively. The highest grain yield was recorded in P_3FM_0(three passing (P_3) of a power tiller and recommended dose of fertilizers) treatment. They concluded that root mass density positively correlated with soil moisture content and grain yield, but negatively with bulk density.

2.1.2. Effect of Management Practices and Intensive Cropping on Soil Organic Matter (SOM) Content

In general, the organic matter content of Bangladesh soils is low. Bhuiyan (1988) reported the organic matter contents of 17 soil series, each from 17 general soil types of Bangladesh. According to him, peat had the highest (35.37%) organic matter content followed by acid basin clays (5.20%) and acid sulphate soils (3.46%). But, these soils are not agriculturally important, as they have some constraints to crop production. Among the remaining 14 soil series, only 4 soil series had more than 2% organic matter while other 10 soil series had below 2%. The overall organic matter content is usually low in the agriculturally important soils in Bangladesh.

Islam *et al.* (1992) stated that organic matter ranged from 0.6 to 1.7% in 29 soil series from different regions of the country. Islam (1990) opined that at least 2% organic matter should be present in the soil for successful crop production. But, he observed that 90% soils of Bangladesh contained 0.5 - 1.0% organic matter. Organic matter content of most of the Bangladesh soils is very low where the majority fall below the critical level (1.5 percent). The OM content of Bangladesh soils in continuously cropped areas has been depleted (Ali *et al.*, 1997). Katyal *et al.*, (2001) reported that a decline in organic matter is considered to create an array of negative effects on crop productivity.

The SOM is an important source of inorganic nutrients for plant production in natural and managed ecosystems (Fritzsche *et al.*, 2002). It governs structural stability and cation exchange capacity of soils either directly through its chemical structure and surface properties, or indirectly as a source of energy and nutrients for soil biota (Zech *et al.*, 1997). These effects are especially important in cultivated tropical soils, where SOM is frequently related to soil fertility and productivity (Fritzsche *et al.*, 2002). Schoenau and Campbell (1996) stated that SOM content has a large impact on both soil quality and nutrient cycling. Decomposition of SOM releases nutrient for plant uptake. Generally, 2 to 5 % of SOM decomposes annually (Paul and Clark, 1996).

The SOM is composed mainly of 55% C, 5 - 6% N, and 1% P and S (Howarth *et al.*, 2002). It is a large reservoir of C that can act as a sink or source of atmospheric carbon dioxide (Lugo and Brown, 1993). It is also an important source of inorganic nutrients for plant production in natural and managed ecosystems (Fritzsche *et al.*, 2002). Mann *et al.* (2006) found that continuous growing of maize - wheat - cowpea cropping sequence over the years with the use of inorganic fertilizers and farmyard manure markedly increased organic carbon content of soil over the control.

Changes in organic matter content may depend on the level of organic matter initially present in the soil (Grant *et al.*, 2002). The combined use of mineral and organic sources of nutrients in soil fertility management is a new approach which evolved from long experiences in soil fertility management (Bationo and Waswa, 2011).Most cultivated soils of Ethiopia are poor in OM contents due to low amount of organic materials applied to the soil and complete removal of the biomass from the field (Yihenew, 2002). Biological degradation is frequently equated with the depletion of vegetation cover and OM in the soil, but also denotes the reduction of beneficial soil organisms that is important indicator of soil fertility (Oldeman, 1993).

In a 21-yr field experiment conducted for the rice (*Oryza sativa* L.)–lentil (*Lens esculenta* Moench) cropping sequence, Srinivasarao *et al.* (2011) concluded that the application of FYM (or other organics) in conjunction with mineral fertilizers is essential to maintaining and enhancing the SOC stock in the rice-based cropping systems. They reported that the application of farmyard manure (FYM) without and with mineral fertilizers increased C input and SOC concentration and stock. They suggested that a minimum quantity of 2.47 Mg C ha^{-1} yr^{-1} is required for soil, climate, cropping system, and fertilization treatments for maintaining a stable SOC level.

In a field experiment with Chickpea-Mungbean-T. amancropping pattern during two years period in Low Ganges River Floodplain Soils (AEZ-12),Quddus *et al.* (2012) found that the organic matter, total nitrogen, phosphorus, sulphur, zinc, and boron content were higher in soil test based fertilizer treatment. They observed the lowest seed and stover/straw yields of all the crops in control treatment. They concluded that the soil test based fertilizer dose considered as suitable dose for this cropping pattern that ensure higher yield and increase soil fertility.

2.1.3. Effect of Management Practices and Intensive Cropping on Some Soil Properties

2.1.3.1. Effect on Soil pH and Acidity

Soil pH is the deciding factor for the availability of essential plant nutrients (Rahman and Ranamukhaarachchi, 2003). Nitrates and phosphates are taken up at higher rates in weak acidic conditions (Mengel and Kirkby, 1982). Fageria and Baligar (1998) found that soil pH and base saturation are important soil chemical properties that influence nutrient availability and crop growth. The soil pH influences the occurrence and the activities of soil microorganisms and eventually affects both organic matter decomposition and nutrient availability (Mengel and Kirkby, 1982).

Urkurkar*et al.* (2010) observed that the application of green manure along with 50% of recommended dose of fertilizer was the most favourable treatment to have highest available N (255 kg ha^{-1}) in surface soil. The available P content of soil increased significantly with farmyard manure, composted rice straw and green manure in conjunction with 50% recommended dose of fertilizer over initial value and control. Mann *et al.* (2006) found that continuous addition of inorganic fertilizers resulted decrease in soil pH.

Mian and Eaqub (1980) found that N, P and K alone and in combination had no effect on soil pH but the application of farmyard manure and green manure slightly decreased the pH value. Organic carbon content was increased with chemical fertilizer in combination with FYM and green manure but decreased due to chemical fertilizer only.

2.1.3.2. Effect on Cation Exchange Capacity (CEC)

The CEC of a soil is strongly affected by the amount and type of clay, and amount of OM present in the soil (Curtis and Courson, 1981). Both clay and colloidal OM are negatively charged and therefore can act as anions (Kimmins, 1997)**.** As a result, these two materials, either individually or combined as a clay-humus complex, have the ability to adsorb and hold positively charged ions (cations). Soils with large amounts of clay and OM have higher CEC than sandy soils low in OM. In surface horizons of mineral soils, higher OM and clay contents significantly contribute to the CEC, while in the subsoil particularly where Bt horizon exist, more CEC is contributed by the clay fractions than by OM due to the decline of OM with profile depth (Foth, 1990; Brady and Weil, 2002).

Patiram and Singh (1993) conducted a four years long field experiment on the effect of continuous application of manures and nitrogenous fertilizer on some properties of acid Inceptisol and found that the CEC of soil had increased by the application of manure. A significant increase in CEC of soil with the application of farmyard manure was also found by Swarup (1979) through a field study on the effect of intensive cropping and manuring on soil properties and crop yields.

A long term (I985 - 97) field experiment with rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) sequence was carried out by Sharma*et al.* (2001) and found that integrated use of inorganic and organics through farmyard manure, crop residues of wheat and green manuring of dhaincha improved the organic carbon, cation exchange capacity and water holding capacity significantly with remarkable decrease in bulk density.

2.1.3.3. Effect on Carbon to Nitrogen Ratio

Carbon (C) to nitrogen (N) ratio (C/N) is an indicator of net N mineralization and accumulation in soils. Organic matter rich in carbon provides a large source of energy to soil microorganisms. Consequently, it brings population expansion of microorganism and higher consumption of mineralized N. Dense populations of microorganisms inhibit the upper soil surface and have an access to the soil N sources. If the ratio of the substrate is high there will be no net mineralization and accumulation of N (Attiwill and Leeper, 1987). They further noted that as decomposition proceeds, carbon is released as CO_2 and the C/N ratio of the substrate falls. Conversion of carbon in crop residue and other organic materials applied to the soil into humus requires nutrients (Lal, 2001).

The basic premise behind C:N ratio is that organic carbon is the primary source of energy for soil microbes, but these also require nitrogen to multiply and utilize this energy. As the active fraction of the OM is degraded due to microbial activity, the C:N ratio drops until a steady state (the passive fraction) is finally attained. The active fraction of the OM may have a C:N ratio between 15 - 30, the slow fraction typically 10 - 25, with the passive fraction stabilizing around 7 - 10 (Brady and Weil, 2002).

2.1.4. Effect of Management Practices and Intensive Cropping on Nutritional Status of Soil

Nutritional status of Bangladesh soils was critically evaluated by reviewing the studies which have been carried out in universities and research institutes of Bangladesh. Almost all upland soils are low in organic matter and deficient in N. Availability of P to the crops is a problem mainly in calcareous soils of Ganges floodplain and acidic soils of terrace and hill areas. Status of K is not a great problem in floodplain areas, but terrace and piedmont soils are not capable of supplying enough K to the crops. Although P and K deficiencies are not severe, addition of these two nutrients is a must for getting higher yield (Moslehuddin *et al.*, 1997). Ranamukhaarachchi *et al.*(2005) stated that nutritional status or soil fertility decline often threatens food production, inducing poverty in developing countries. According to Rahman and Ranamukhaarachchi (2003) soil fertility often changes in response to land use systems and land management practices. The use of chemical fertilizers mainly for NPKS has been increasing steadily but they are not applied in balanced proportion (Islam and Haq, 1998).

2.1.4.1. Effect on Total Nitrogen

Nitrogen (N) is the fourth plant nutrient taken up by plants in greatest quantity next to carbon, oxygen and hydrogen, but it is one of the most deficient elements in the tropics for crop production (Mesfin, 1998). The total N content of a soil is directly associated with its OC content and its amount on cultivated soils is between 0.03 and 0.04% by weight (Mengel and Kirkby, 1987). Nitrogen (N) is the nutrient that is most frequently limiting to crop production and the nutrient applied in the greatest amounts (Campbell *et al.*, 1986).

Like other tropical and subtropical soils, Bangladesh soils have long been categorized as poor in soil fertility because of low N supplying capacity (Islam, 1983). Nitrogen is the most limiting factor in crop production. The total N content of Bangladesh soils is in a range of 0.02 to 0.12% (Ahsan and Karim, 1988). Portch and Islam (1984) studied 63 soil samples from different regions of Bangladesh and found that 100% of them were deficient in N. Islam *et al.* (1992) reported analytical data of 29 soil series; all had the N content below the critical level. Moslehuddin (1993) also found N deficiency in all of the 86 soil samples from Old Brahmaputra Floodplain. Ali *et al.* (1981) reported very low N contents in most areas of Bangladesh.

The N content is lower in continuously and intensively cultivated and highly weathered soils of the humid and sub-humid tropics due to leaching and in highly saline and sodic soils of semi arid and arid regions due to low OM content (Tisdale *et al.*, 1995). The considerable reduction of total N in the continuously cultivated fields could be attributed to the rapid turnover (mineralization) of the organic substrates derived from crop residue (root biomass) whenever added following intensive cultivation (McDonagh *et al.*, 2001).

An efficient cropping system will attempt to balance crop demands for N with timing and rate of N supply so that crop yield is optimized while N is neither over-depleted from the soil nor accumulated in quantities that results in the contamination of ground waters or surface waters (Grant *et al.,* 2002). With increased nutrient removal, responses to fertilizer application become more likely (Campbell *et al.*, 1991). Paikaray*et al.* (2002) reported that soil fertility in terms of available N (5.8-22.0 kgha^{-1}) increased under green-manure, wheat-straw incorporation, summer cowpea fodder and at higher levels of inorganic N.

Timsina *et al.* (2006) observed that N is being removed from the rice - wheat cropping system than is being added through fertilizer and or BNF. They said that without changing fertilizer practice, the adoption of high yield potential rice and wheat cultivars will likely accelerate mining of N and other nutrients from the soil. Yadav (1998) observed decrease in total soil N after a few years of rice - wheat cropping sequence. In a two-years study on rice - rice and rice - maize cropping sequences in the Philippines an increase (2 to 9%) of total soil N in rice - rice and a decrease of 3% total soil N in rice - maize system were observed (Witt *et al.*, 2000).

Changing from a wheat-fallow to a wheat - corn - fallow rotation required a 44% increase in N fertilizer inputs (Kolberg *et al.*, 1996). Therefore, in intensive cropping systems, N fertilization becomes increasingly important. Ranamukhaarachchi *et al.* (2005) studied soil N dynamics in highlands and medium highlands of Bangladesh and observed that there was no significant effect of cropping systems on soil N. They reported that the observed low N content of the soils after the study was due particularly to low organic matter content and partially to losses. Shaktawat and Shekhawat (2010) reported that the application of farmyard manure significantly increased the available nitrogen content in soil compared with the control.

Maitra *et al.* (2008) found that application of phosphorous and farmyard manure had significantly improved the available nitrogen, phosphorous and potassium status in post-harvest soil after 2 years of cropping. Paikaray*et al.* (2002) reported that soil fertility in terms of organic carbon (0.03-0.06%), available N (5.8-22.0 kgha^{-1}), P (1.4-3.8 kg ha^{-1}) and K (2.2-17.9 kg ha^{-1}) increased under green-manure, wheat-straw incorporation, summer cowpea fodder and at higher levels of inorganic N. Only available K had negative balance in soils of cowpea fodder and the control plots and at lower levels of nitrogen.

From a study to assess the effect of three different sources of nutrients on soil fertility status in an adult arecanut (*Areca catechu* L.) plantation during 2008-09 and 2010-2011, Acharya *et al.* (2015) found that the available N content was highest (332.6 and 242.3 kg ha^{-1} at 0-30 and 30-60 cm soil depth, respectively) in the soil applied with vermicompost, whereas the soils applied with chemical fertilizer recorded maximum available P and K content. They proposed that long-term application of compost improved soil physicochemical properties, available N content and also microbial population except available P and K content in soil which collectively resulted increased kernel yield of arecanut.

In a field experiment with soybean (*Glycine max* L. Merr.)-durum wheat (*Triricum durum* Desf.) cropping system during 2003-06 period, Ramesh *et al.* (2008) reported that soil organic carbon, available N, P and K status of soil were significantly improved in organic manure treatments compared to chemical fertilizers. Das *et al.* (2006) found that the application of FYM could either maintain or improve the soil fertility status as was evident by the post harvest soil available NPK status, especially when fertilizer N was also added. They concluded that application of FYM@12 tha^{-1} could save fertilizer N to the tune of 30 kgha^{-1} and thereby economize fertilizer use in cotton cultivation.

More (1994) concluded from 3-years study that application of 25 t ha^{-1} FYM plus 20 t ha^{-1}pressmud decreased the soil pH and increased organic matter content and availability of N and K in soil. Organic matter and urea-N improved the organic carbon content of soil significantly. Available nitrogen content was improved significantly only due to addition of urea-N (Nahar *et al.,* 1996).Ullah*et al.* (2008) observed that the organic matter content and availability of N, P, K and S in soil were increased due to application of organic matter.

Ayoola and Makinde (2009) concluded after two years of fertilizer application and cropping that poultry manure increased soil N, P and K contents by 41.7%, 1.8% and 3.4%, respectively, while fortified cow dung increased the nutrients by 25%, 0.33% and 3.4%, respectively. Although both organic manures increased the soil N and P, poultry manure gave higher values while the soil K, Ca and Mg contents were more increased with the cow dung than poultry manure.

Mann *et al.* (2006) found that the application of farmyard manure with optimum inorganic fertilizers increased the available N content of the soil significantly. Correlation and regression analysis indicated that the mineral N and available N influence the applied N behaviour in the long-term fertilizer experiment soils.

Yaduvanshi and Sharma (2010) reported that the actual soil N balance was much lower than the expected balance indicating large losses of N from the soil after carried out an experiment with rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) system. The net balance of P and K was also negative under 2 levels of fertilizer NP application, i.e. 75 and 100% recommended doses of N and P for each crop with and without different organic manures, i.e. 10 t ha^{-1} farmyard manure, 10 tha^{-1} sulphitation pressmud, *in situ* green manuring as *Sesbania bispinosa* green manure and 2.5 t ha^{-1}wheat residue to rice crop only.

2.1.4.2. Effect on Available Phosphorus

Phosphorus (P) is known as the master key to agriculture because lack of available P in the soils limits the growth of both cultivated and uncultivated plants (Foth and Ellis, 1997). Bhuiyan (1988) reported that available P of Bangladesh soils ranged from 2 to 14 ppm with a mean value of 12 ppm. Islam *et al*. (1992) reported that available P determined by the Agro Service International method varied from 2 to 18 ppm in 29 soil series from all over the country; most of them were below the critical level (12 ppm).

Egashira and Yasmin (1990) found that the total P contents of all of the 10 floodplain soils of Bangladesh were well above the critical level and that the soil of terrace area had the content just above the critical level, and they opined that total P was enough to sustain the normal growth of rice. But the available P contents were above the critical level, depending on the clay content, in the soils of Non-calcareous Tista and Brahmaputra Floodplains and Piedmont Alluvial Plains, whereas they were below the critical level in the soils of Calcareous Ganges River Floodplain and Barind Tract.Shaktawat and Shekhawat (2010) reported that the application of farmyard manure significantly increased available phosphorus content in soil compared with the control.

Following N, P has more wide spread influence on both natural and agricultural ecosystems than any other essential elements. In most natural ecosystems, such as forests and grasslands, P uptake by plants is constrained by both the low total quantity of the element in the soil and by very low solubility of the scarce quantity that is present (Brady and Weil, 2002). Erosion tends to transport predominantly the clay and OM fractions of the soil, which are relatively rich in P fractions. Thus, compared to the original soil, eroded sediments are often enriched in P by a ratio of two or more (Brady and Weil, 2002). According to Foth and Ellis (1997), natural soil will contain from 50 to over 1,000 mg of total P per kilogram of soil. Of this quantity, about 30 to 50% may be in inorganic form in mineral soils.

Phosphorus, nitrogen and other nutrients need to be available to the crop in balance to optimize crop yield and quality and efficiency of crop production (Halvorson and Black, 1985). Cropping intensification and diversification will influence both P supply and demand in cropping systems (Grant *et al.*, 2002). Mckenzie *et al.*(1992) evaluated the effect of cropping system and fertilizer management on P in two long-term rotation studies in Alberta. They found that without fertilizer application, continuous cropping resulted in the greatest reduction of almost all soil organic and inorganic P pools. However, when continuous cropping was coupled with the addition of N and P fertilizers, there was a positive effect of cropping on P availability (Selles *et al.*, 1995).

Bowman and Halvorson (1997) reported the increases in P availability under a continuous cropping system compared with wheat - fallow systems even though P inputs were generally greater in the latter system. The increased P availability was attributed to redistribution of soil P from lower depths through biocycling in residue and litter production. The type of crop grown will also influence P depletion because crops differ in their yield potential and in the amount of P removed in the harvested portion. Selles *et al.* (1995) reported that P exported from the system was higher in cereals (4.9-7.4 $kgha^{-1}y^{-1}$) than in the lower yielding flax and lentil (3.3-3.7 kg ha^{-1} y^{-1}). Increasing crop yield will increase P removal, but there may not be as great an impact on the P fertilizer requirements as there is with N because the amount of P removed by crops is small relative to the total P in most soils (Roberts *et al.*, 1999). Gopinath and Mina (2011) found that the application of farmyard manure 10 t ha^{-1}+ recommended NPK, recorded significantly higher available P than plots under control.

2.1.4.3. Effect on Exchangeable Potassium and Sodium

Wakene (2001) reported that the variation in the distribution of K depends on the mineral present, particle size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed. Soil K is mostly a mineral form and the daily K needs of plants are little affected by organic associated K, except for exchangeable K adsorbed on OM. Mesfin (1996) described low presence of exchangeable K under acidic soils while Alemayehu (1990) observed low K under intensive cultivation. Normally, losses of K by leaching appear to be more serious on soils with low-activity clays than soils with high-activity clays, and K from fertilizer application move deeply (Foth and Ellis, 1997). Cassman (1995) reported that K availability and uptake were increased with increasing organic matter.

Except nitrogen, potassium is a mineral nutrient that plants require in the largest amounts (Marschner, 1995). Potassium is the third major nutrient deficient in most of Bangladesh soils. Previously, there was a general impression that Bangladesh soils have sufficient amounts of K and that there is no need for any potash fertilizer application. However, due to intensification of farming in recent years, well-spread responses to added potash fertilizer have been observed (Islam *et al.*, 1985). Ranamukhaarachchi *et al.*(2005) studied soil fertility and land productivity under different cropping systems and observed that the cropping systems had no significant effects on K content in soil in both highlands and medium highlands. Srinivasa *et al.*(1999) reported a significant decline in K release due to continuous cropping. Mehla *et al.* (2008) noted that the balanced application of NPKZn with and without organic amendments increased the available K status of soil over their initial value.

Islam *et al.* (1992) observed that the exchangeable K content of 29 soil series from different areas of Bangladesh ranged from 0.07 to 4.7 c mol kg^{-1} soil. Urkurkar*et al.* (2010) reported that continuous use of fertilizers and intensive cropping had resulted in lowering the available K status of soil indicating the need of application of K to meet the crop requirement. Mann *et al.* (2006) observed that the available K content also improved and maximum amount was noticed where farmyard manure was added with inorganic fertilizers.

Shaktawat and Shekhawat (2010) reported that the application of farmyard manure significantly increased the available nitrogen, phosphorus and potassium content in soil compared with the control.Mian *et al.* (1983) found some beneficial effect of N, P and FYM on organic carbon but their effects on exchangeable K were very negligible. Sharma and Sharma (1994) observed that the application of organic fertilizer increased soil organic carbon content and availability of soil N, P and K.

In a study with different cropping systems, Sadananda and Mahapatra (1972) observed that the exchangeable K in soils increased after potato, maize and groundnut crops whereas, it decreased after rice and jute cropping systems. Potato requires high amount of K for tuber bulking (BARC, 2012). Increases in soil K depletion have been observed in India. The categories of low and high levels of available K in soils have decreased by 0.6% and 6.4% respectively, while the area of the medium category increased by 7% (Hasan, 2002). In many cases where levels of soluble K in the soil are high, plants tend to take up more K than they really need (Zublena, 1997).

Lee *et al.* (2004) conducted a two years long field experiment and reported that sodium content in soils was increased due to the application of compost. Exchangeable sodium (Na) alters soil physical and chemical properties mainly by inducing swelling and dispersion of clay and organic particles resulting in restricting water permeability and air movement and crust formation and nutritional disorders (decrease solubility and availability) of calcium (Ca) and magnesium (Mg) ions (Sposito, 1989). Moreover, it also adversely affects the population, composition and activity of beneficial soil microorganisms directly through its toxicity effects and indirectly by adversely affecting soil physical and as well as chemical properties. In general, high exchangeable Na in soils causes soil sodicity which affects soil fertility and productivity.

2.1.4.4. Effect on Available Sulphur

Among the secondary nutrients, deficiency of S is the most serious in Bangladesh. Even it may have to be considered as the second most deficient nutrient, just after N. Sulfur deficiency in Bangladesh soils is getting widespread and acute (Islam, 1983). Most of Bangladesh soils are deficient in available sulphur which roughly covers 44% of the total cropped area (Hussain, 1990). Portch and Islam (1984) found that 68% of the soils were below the critical level for S. Egashira and Yasmin (1991) studied 10 floodplain and 1 terrace soils, and found that total S was not enough to sustain the normal plant growth.

The major reserve of this element in soil is the organic fraction, which has been estimated to be 80-90 percent of the total sulphur in most of the soils. Release of sulphur from this fraction depends on several factors like moisture, temperature, pH and CEC (Swift,1985).The total S content of soils is variable. Total S in soils may range from near zero to about 0.06 percent. However, most of the soils contain 0.01 to 0.05 percent S (Burns, 1967).

Generally, the total S content of tropical soils is low because of their organic matter content (Blair *et al.*, 1979). Total S is directly related to available S in soil while SO_4^{2-}-S is a good index of plant status. Organic S is present in the soil in two forms: Carbon bonded S and non-carbon bonded S (Mengel and Kirkby, 1982). The later is also called ester sulphate or reducible-S. The C:N:S ratio in soil organic matter is approximately 125:10:1.2 (Freney and Stevenson,1966). Sulphur input in soils may come from the following sources: rainfall, irrigation water, fertilizer (Walker and Gregg, 1975), farm manures and crop residues (Manarial and Gonzalez, 1987).

2.1.4.5. Effect on Exchangeable Calcium and Magnesium

Calcium (Ca) is one of the essential elements obtained from the soil by plants and used in relatively large quantities. Andrews and Norris (1961) carried out an experiment between two legumes, one temperate and one tropical to find their differential response to varying levels of calcium on poor soils. Their result showed that the temperate legume produced slight growth and three weeks symptoms in the form of upward cupping of the first trifoliate leaves.

Soils in areas of moisture scarcity (such as in arid and semi-arid regions) have less potential to be affected by leaching of cations than do soils of humid regions (Jordan, 1993). Soils under continuous cultivation, application of acid forming inorganic fertilizers, high exchangeable and extractable Al and low pH are characterized by low contents of Ca and Mg mineral nutrients resulting in Ca and Mg deficiency due to excessive leaching (Dudal and Decaers, 1993).

Higher soil Ca and Mg levels have been reported in no tillage system compared with conventional tillage (Ferrer, 1984) but Blevins *et al.*(1977) found no significant effects on exchangeable Ca under different tillage methods. Higher Ca and Mg contents were found in the oat/soybean soil surface compared to the oat/grain sorghum cropping systems (Ruben and Gallaher, 1976).IRRI (1975) reported that incorporation of organic matter returned Ca to the soil.

Exchangeable Mg commonly saturates only 5 to 20% of the effective CEC, as compared to the 60 to 90% typical for Ca in neutral to somewhat acid soils (Brady and Weil, 2002). Research works conducted on Ethiopian soils indicated that exchangeable Ca and Mg cations dominate the exchange sites of most soils and contributed higher to the total percent base saturation particularly in Vertisols (Mesfin, 1998). Different crops have different optimum ranges of nutrient requirements. The response to calcium fertilizer is expected for most crops when the exchangeable Ca is less than 0.2 cmol kg^{-1} of soils, while 0.5 $cmolkg^{-1}$ soil is reported to be the deficiency threshold level for Mg in the tropics (Landon, 1991).

According to Hesse (1998) Mg occurs in soil, principally in the clay minerals, being common in micas, vermiculites and chlorites. Welte and Werner (1963) investigated the uptake of Mg by plants as influenced by hydrogen, calcium and ammonium ions. They found that hydrogen ions suppressed Mg uptake most and with a strongly acid substrate, Mg deficiency could be remediated by applying Mg and as a consequence the pH raised. Zublena (1997) stated that depletion of Ca and Mg reserve in the soil by crop removal is rarely a problem in limed soils because of the large quantity of these nutrients that are present in liming materials. However, some crops, such as peanuts, may require more Ca than the crops can remove.

2.1.4.6. Effect on Micronutrients (Fe, Mn, Zn and Cu)

Among the nine micronutrients, data on the status of Cu, Fe, Mn, Zn, and B of Bangladesh soils are available while the Cl and Mo status is yet to be studied. Of the five elements studied, Fe has never been reported to be deficient, whereas Zn and B are the most widely deficient and Cu and Mn are deficient in some areas (Islam, 1992). Emerging deficiency of micronutrients like Zn, B, Mn, Mo has been reported in some parts of Bangladesh particularly northwestern region. It is now well known that S and Zn deficiencies particularly in wet land rice soils in many parts of the country have been induced by imbalanced fertilization (Ali *et al.*, 1997).

Tisdale *et al.*(1995) stated that micronutrients have positive relation with the fine mineral fractions like clay and silt while negative relations with coarser sand particles. This is because their high retention of moisture induces the diffusion of these elements. Soil OM content also significantly affects the availability of micronutrients. Krauskof (1972) stated that the main source of micronutrient elements in most soils is the parent material, from which the soil is formed. Iron, Zn, Mn and Cu are somewhat more abundant in basalt. Brady and Weil (2002) indicated that the solubility, availability and plant uptake of micronutrient cations (Cu, Fe, Mn and Zn) are more under acidic conditions (pH of 5.0 to 6.5).

From a study on extractable micronutrients, Richards*et al.* (2010) observed that the application of inorganic P had little effect on micronutrient availability. However, long-term application of biosolids significantly ($p< 0.05$) increased extractable Cu, Fe, Mo, and Zn in soil, while long-term application of beef manure significantly increased all the micronutrients evaluated. Similarly, the long-term application of swine effluent significantly increased extractable B, Cu, Mo, and Zn in soil. They also found that the addition of micronutrients from organic amendments increased micronutrient availability, while long-term inorganic P application had little effect. They concluded that the organic amendments make an ideal fertilizer source for areas with micronutrient deficiencies.

Zinc deficiency was observed in the studies by the workers of Bangladesh Rice Research Institute (BRRI, 1980 and Mukhopadhayay *et al.*, 1986). In general, Ganges Floodplain and coastal saline soils and the area covered by HYV rice are deficient in Zn. Yield increase in rice was reported as high as 27% due to Zn application. This indicates that although Zn requirement of a crop is very small, still its application cannot be overlooked particularly in the areas prone to Zn deficiency (Ali, 1991).

Mondal *et al.* (1991) found that in the Old Brahmaputra Floodplain soil, application of Zn and B increased the yield of transplanted aman rice (BRll) by 11 and 8%, respectively, but application of Cu and Mo had no such positive effect. In wheat, 21% (Jahiruddin *et al.*, 1995), and 30 and 55% (Jahiruddin *et al.*, 1992) yield increases were recorded due to application of B. Jahiruddin *et al.*, (1992) got no response of wheat to applied Cu and Mo. Islam (1992) reported that the application of Zn increased the yield of boro rice, T. aman rice, maize, and chickpea by 2, 11, 36, and 34%, respectively, over control (no zinc). Mann *et al.* (2006) reported that micronutrient availability also increased with the continuous use of farmyard manure.

Nayyar and Chhibba (2000) conducted an experiment with *Sesbania* green manure and observed the significant increase in micronutrients, particularly Fe and Mn. Singh *et al.* (2000) conducted a long term experiment and found that recycling of crop residues increased the availability of micronutrients in the soil generally similar to that with green manuring. The DTPA-extractable zinc (Zn), iron (Fe) and Manganese (Mn) increased with the incorporation of organic amendments. Schlegel (1992) found that soil Fe levels were increased slightly (1 ppm) by compost application. Whalen *et al.* (2000) reported that extractable Fe declined slightly after manure application, but did not differ significantly in manure amended and unamended soils.

2.1.5. Effect of Nutrient Management Practices and Intensive Cropping on Crop Yield

The modern agriculture depends mostly on chemical fertilizers. Continuous and imbalanced use of inorganic fertilizers leads to decline or stagnation in productivity due to limitation of one or more nutrients (Singh *et al.*, 2006). In cropping system, efficient utilization of nutrients is very important. Crops grow in a sequence should aim at maintaining soil fertility and productivity because of the large quantities of fertilizer nutrients required and recovered by intensive cropping systems (Bobde *et al*., 1998).

Rao and Moorthy (1994) observed that combined application of organic and inorganic fertilizer was found to increase the grain yield of rice over organic or inorganic fertilizers applied alone. Application of organic and inorganic fertilizers in equal proportions was found to produce higher and sustained yield in irrigated rice.

2.1.5.1.Effect on Jute Yield

Maitra*et al.* (2008) conducted a field experiment with sunnhemp (*Crotalaria juncea* L.) - wheat (*Triticum aestivum* L. emend Fiori & Paol.) cropping system during 2004 and 2005. They observed the highest jute fibre yield (4.90 t ha^{-1}) with combined application of phosphorus and farmyard manure which was 45.2% higher than the yield of the treatment without phosphorus and farmyard manure.

Gani *et al.* (2001) conducted an experiment during 1994-95 to study the effects of poultry manure (0.25, 0.50, 0.75, 1.00, 2.00 or 3.00 t ha^{-1}) on the growth and yield of jute (*Corchorus olitorius* cv. O-9897). They mentioned that plant height, green weight with and without leaves, dry fibre weight and stick weight significantly increased with the application of poultry manure. The greatest improvement in the yield of jute was obtained with 2 t ha^{-1} poultry manure at 0.5 t ha^{-1} and 90 kg N + 10 kg P + 10 kg S ha^{-1}.

Alim (2003) conducted two sets of experiments to evaluate the impact of N and K application on growth, yield and nutrient uptake of jute. The application of N fertilizer exhibited significant effects on growth and yield of jute. The highest fibre (3.94 t ha^{-1}) and stick (9.52 t ha^{-1}) yield were recorded with 150 kg N ha^{-1} application. On the other hand, the potassium level up to 150 kg K ha^{-1} application significantly increased the dry fibre and stick yield of jute. The highest fibre (4.38 t ha^{-1}) and stick yield were recorded with application of 150 kg K ha^{-1}. Besford (1979) reported that high levels of nitrogen increased the uptake of P when an adequate level of this nutrient was supplied.

Mazumdar *et al.* (2014) conducted a study with an aim to observe the effect of inorganic fertilizers, with or without organic manure on yield after forty two years of jute - rice - wheat sequence. The treatments selected for the study were 50% NPK, 100% NPK, 150% NPK, 100% NP, 100% N, 100% NPK+FYM, control. The investigations revealed that jute yields were lowest in the control where neither fertilizers nor manures were applied for the last four decades and highest in 150%NPK application. Alam *et al.* (1991) found that N and K uptake by jute stick with bark increased with increasing NPKS fertilizers. The range of P removal was between 7.81 and 28.22 kg P ha^{-1} depending on the varieties used, fertilizer and location. The uptake of S by different parts of jute ranged from 2.05 to 3.23 kg ha^{-1} in root, 3.99 to 9.27 kg ha^{-1} in bark, 9.86 to 17.09 kg ha^{-1} in stem and 4.06 to 5.81 kg ha^{-1} in leaves.

Brahmachari and Mondal (2000) conducted an experiment during 1994-1996 to evaluate crop productivity and soil fertility building under jute (*C. olitorius*), Rice - Rape (*B. campestris* Var. oleifera) cropping sequence. The highest fibre yield of jute yield was obtained when jute crops in sequence received both organic and inorganic sources of nutrients (N:P:K at 40:20:30 kg $ha^{-1}$and 10 t FYM ha^{-1}). Ray *et al.* (2000) reported that yield targets were attained for jute (cv. JRO 7835) 2.5 to 3 t^{-1}ha , with ±10% variation from the desired yield targets. They concluded that phosphorus application to jute could be omitted in soils having available P above 10.5 kg^{-1} evaluated as a critical limit.

Ahmed *et al.* (1999) carried out an field experiment during 2007 to find out the effect of NPKS on growth, yield and nutrient uptake by jute (cv. BINA deshipat-1). They found that plant growth, fibre and stick yield was significantly higher in all treatments over the control. Bangladesh Jute Research Institute (BJRI) reported that all the treatments had significant effect on the white jute (*Corchorus capsularis*) var. BJC-2197 over control (Annos., 1986). Alam and Alam (1992) observed that the application of recommended dose of NPK produced significantly higher fibre yield.

2.1.5.2. Effect on Rice Yield

In a study on integrated nutrient management in the Bush bean - T. aus - T. aman cropping pattern over three years, Rahman*et al.* (2009) found positive effect of crop residue recycling and residual effect of cow dung on the yield of the next crops. Both the soil test based fertilizer and the cow dung with IPNS basis fertilizer treatments gave higher pod yield of bush bean. For T. aus rice, the highest yield was obtained with the treatment where bush bean stover was used along with IPNS based chemical fertilizer. Again the highest yield of T. aman rice was observed in the residual effect of cow dung with reduced amount of fertilizer treatment.

Bhuiyan*et al.* (2011) carried out a three years long field experiment with Wheat - T. aus/Mungbean - T. aman cropping pattern in the Old Brahmaputra Floodplain Soils

(AEZ 9, Aeric Haplaquept). They found that grain (3.46 t ha^{-1}) and straw yields (5.19 t ha^{-1}) of T. aus rice increased significantly due to application of fertilizers. They observed remarkable increase in crop yield due to application of NPKS (HYG) fertilizers. The lowest grain yield and the lowest nutrient uptake were noted in control plots receiving no fertilizer or manure.

Sarker*et al.* (2015) found significant variation in growth and yield parameters as well as in nutrient content of aman rice due to application of combined organic manure and inorganic fertilizer treatments. They recorded higher grain yield (4.18 t ha^{-1}) in 100% inorganic fertilizer + 5 t PM ha^{-1} which was statistically similar with 50% of recommended dose of S + 5 t PM ha^{-1} (4.13 t ha^{-1}) whereas lowest grain yield (3.67 t ha^{-1}) was from sole PM. Rahman *et al.* (2012) found that the incorporation of *Sesbania* biomass and mungbean residue along with inorganic fertilizers for MYG produced identical grain yields of T. aman rice with the fertilizers alone for HYG. The highest grain yield 4.31 t/ha was found in IPNS dhaincha along with fertilizers for HYG treatment. Vanaja and Raju (2002) reported that different combinations of chemical fertilizers with organic manure produced the highest grain and straw yields of rice.

Singh and Agarwal (2005) observed that the application of recommended N, P and $ZnSO_4$ (120 + 25 + 26.2 kg ha^{-1}) along with farmyard manure @ 10 t ha^{-1} resulted in significantly higher rice grain yield (4259 and 3653 kg ha^{-1}) than other treatment combinations. The combined effect of farmyard manure and N levels showed that the agronomic efficiency increased substantially (24.9 and 25.8) at 10 t ha^{-1} farmyard manure along with 60 kg N ha^{-1}. Kang and Balasubramanian (1990) also found that high and sustained crop yields could be obtained with judicious and balanced NPK fertilization combined with organic matter amendments.Maskina *et al.* (1988) reported that poultry manure increased the yield of rice grain which was 2.6 times higher than that with cattle manure.

In a long-term field experiment with rice (*Oryza sativa* L.) – horsegram [*Macrotyloma uniflonan* (Lanl.) Verd.] cropping sequence, Pal *et al.* (2006) observed that the yield of rice was 1.87 t ha^{-1} in the treatment receiving 30 kg N ha^{-1} through farmyard manure whereas the yield of rice was 1.84 t ha^{-1} with the treatment receiving 50% N through chemical fertilizer and 50% N through farmyard manure that was higher than the chemical fertilizer alone. The use of 50% N through other organic manures like

Glyricidia and Cassia leaves along with 50% of P and K dose of fertilizers were more or less at par with the use of 50% chemical fertilizer.

Duhan and Singh (2002) conducted a field experiment to study the effect of different green manures (fallow, dhaincha, sunhemp, moong) without and with different levels of fertilizer-N (0, 40, 80, 120 kg ha-1) on yield (grain, husk, straw) and uptake of micronutrients (Zn, Cu, Mn, Fe) in submerged rice. They found that the rice yield and uptake of nutrients increased significantly with increasing N levels. Gupta (1995) also reported the highest yield of rice with the combined application of poultry manure and phosphorus fertilizer.

Brohi *et. al.* (2000) found that increasing amounts of potassium and magnesium had significant effect on the rice straw yield. Mg treatment had no significant effect on the rice grain yield. The uptake of all nutrients in straw was increased with K and Mg treatment. However, the K treatments increased the nutrient uptake in grain, whereas Mg treatments significantly enhanced the N uptake in rice grain.Chandra *et al.* (2001) reported that the reduction of recommended fertilizer dose to half along with sunnhemp (Crotalaria juncea L.) green-manuring recorded significantly higher yield of rice than only with the recommended NPK.

Islam *et al.* (2014) carried out an experiment to study the combined effects of *Sesbania* green manure incorporation with different levels of nitrogen fertilizer on the growth and yield of BINA dhan 7. They observed highest grain yield of 5752 kg ha^{-1} and straw yield of 6654 kg ha^{-1} in the plot treated with 75% recommended dose of nitrogen (RDN) and green manure incorporated at 50 DAS. The lowest grain yield (4783 kg ha^{-1}) and straw yield (5154 kg ha^{-1}) were recorded with GM incorporated at 40 DAS + 50% RDN.

Jahan *et al.* (2015) tested twelve nutrient management treatments (with and without crop residue incorporation) to find out the optimum nutrient management practice for grain yield, nutrient balance and economics of T. amanrice. On an average, maximum grain yield of T. amanrice was obtained from soil test based (STB) + CRI (5.24 t ha^{-1}) followed by IPNS + CRI (5.13 t ha^{-1}), STB (5.12 t ha^{-1}), IPNS (5.03 t ha^{-1}), HYG + CRI (4.50t ha^{-1}) and HYG (4.41 t ha^{-1}). Numerically but not statistically higher yield and yield contributing parameters were noticed in CRI plots than without CRI.

Urkurkar*et al.* (2010) found highest rice and wheat yield when 50% of N was supplied through green manure in conjunction with 50% of NPK through inorganic fertilizers

(50% recommended dose of fertilizer + 50% N-green manure) when rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system during 16 years period. They observed significant residual effect of green manure on the following wheat crop, 50% recommended dose of fertilizer + 50% N (green manure) also maintained the sustainability of the system.

Barik*et al.* (2006) found highest grain and straw yields in crops under recommended fertilizer dose along with 10 t vermicompost ha^{-1} which was significantly higher than 100% recommended NPK fertilizers when an experiment conducted for integrated nutrient management of rice (*Oriza sativa* L.). The study suggested that nutrient concentration based application of vermicompost likely to be a more effective proposition than using this material on the basis of total weight, as was generally done for different organic manures. Rahman *et al.* (2007) also reported that straw yield of rice was significantly increased due to residual effect of poultry manure.

Kumawat*et al.* (2006) found that the application of 60 kg N ha^{-1} significantly increased the plant height, dry matter accumulation and number of tillers at all the growth stages and grain yield (5 t ha^{-1}), straw yield (6.73 t ha^{-1}) and net return over 0, 20, and 40 kg N ha^{-1}. The combined application of vermicompost @ 4.5 t ha^{-1} + 40 kg N ha^{-1} gave higher rice grain yield (5.59 t ha^{-1}) and straw yield (7.06 t ha^{-1}) over rest of other combinations of organic manure and nitrogen. Whereas, farmyard manure @ 7.5 t ha^{-1} + 60 kg N ha^{-1} gave maximum net return over rest of the combinations of organic manure and nitrogen.

2.1.5.3. Effect on Mustard Yield

Hossain *et al.* (2011) conducted an experiment for three years to evaluate the effect of B in terms of yield of mustard (BARI Sarisha-8) in calcareous soil. The mustard crop responded significantly to B application. The optimum rate of B was found to be 1 kg ha^{-1} and there was no significant difference between 1 & 2 kg B ha^{-1} in all the years. Boron and N concentrations of grain and stover were significantly increased with increased rate of B application indicating that B had positive role on protein synthesis.

Zamil *et al.* (2004) carried out a pot experiment to find out the effects of different animal manure on yield, quality and nutrient uptake by mustard cv. Agrani. The experiment comprised of two levels of cage system poultry manure, deep litter system poultry manure, cow dung and bio-gas slurry *viz.* 10 and 20 t ha^{-1}, one control and one chemical fertilizer @ recommended dose. Cage system poultry manure @ 20 t ha^{-1} significantly increased the seed and straw yield of mustard and cow dung showed lower performance. The overall results suggest that cage system poultry manure @ 20 t ha^{-1} gave best performance among the parameters studied.Rasool *et al.* (2013) observed that the seed and stoveryield of sunflower were significantly higher with FYM @10 and fertilizers than that of FYM @20 t ha^{-1}.

Kansotia *et al.* (2015) conducted a field study during rabi season to evaluate the effect of vermicompost and inorganic fertilizers on soil properties and yield of Indian mustard (*Brassica juncea*L.). Amongst the treatments, application of vermicompost up to 6 t ha^{-1} and 80 kg N+ 40 kg P_2O_5 ha^{-1}, significantly increased yield and soil properties including higher organic carbon and lower pH compared to the other treatments and control. Results of this study show that use of vermicompost can minimize the quantity of inorganic fertilizers, recycle the farm waste, and increase the physical properties of soil.

Singh *et al.* (2014) conducted a field experiment during rabi seasons to investigate the effect of three levels of FYM (0, 2.5 & 5.0 t ha^{-1}) with two biofertilizers (*Azotobacter* and *Azospirillum*)at the rate of 4.0 kg ha^{-1} each and three levels of N (0, 40 & 80 kg ha^{-1}) on Indian mustard (*Brassica juncia* L., cv. RH-30). The yield attributes and seed as well as stover yield increased significantly with the application of FYM (5.0 t ha^{-1}) over control. Integrated use of bio-fertilizers, FYM with 40 kg of nitrogen gave seed yield equal to the 80 kg N ha^{-1} alone. Maximum seed yield was obtained in the use of higher doses of N fertilizer in conjunctions with bio-fertilizers and FYM in both years.

2.1.5.4. Effect on Lentil Yield

Quddus *et al.* (2014) found that the combination of $Zn_{3.0}B_{1.5}$ produced significantly higher lentil seed yield (1156 kg ha^{-1}) when they conducted a study in Calcareous Low Ganges River Floodplain Soil (AEZ 12). The objectives of the study were to evaluate the effect of Zinc (Zn) and Boron (B) on the yield and yield contributing characters of lentil (*Lens culinaris*Medic) and to estimate the optimum dose of Zn and B for yield maximization. The lowest seed yield (844 kg ha^{-1}) was found in control (Zn_0B_0 combination). The combined application of zinc and boron were superior to their single application. Therefore, the combination of $Zn_{3.0}B_{1.5}$ may be considered as suitable dose for lentil cultivation in Bangladesh. But from regression analysis, the optimum treatment combination was $Zn_{2.85}B_{1.44}$ for Madaripur, Bangladesh.

Upadhyay (2013) conducted a study to observe the effects of sulphur and zinc nutrition on lentil for yield, quality and uptake of nutrients. Application of S upto 30 kg ha^{-1} enhanced the average yield of grain and straw by 34.8 and 28.4% over control, respectively. Application of Zn up to 4 kg ha^{-1} increased the lentil grain and straw yield over control. Significantly higher grain and straw yields of lentil were recorded in the treatment where 4 kg Zn was applied along with 30 kg S ha^{-1}.Murwira and Kirchman (1993) observed that nutrient use efficiency might be increased through the combination of manures and mineral fertilizers. Thus, the combined application of chemical fertilizers and organic manures performed better in terms of yield of lentil grain and stover.

Quddus *et al.* (2012) conducted a field experiment on Chickpea – Mungbean - T. aman cropping pattern under Low Ganges River Floodplain Soils (AEZ-12) to find out the suitable fertilizer doses for this pattern. Among four treatments the effect of T_2 ($N_{130}P_{14}K_{76}S_6Z_{n1.5}B_{1.0}$) treatment was significant at 5% level except seed yield of chickpea in 2008-09. Treatment T_3 ($N_{90}P_{10}K_{15}$) showed significant difference with T_4 (control) treatment. The lowest seed and stover/straw yields of all the crops were recorded in control treatment (T_4). They concluded that the soil test based fertilizer dose (T_1)was considered as suitable dose for this cropping pattern that ensure higher yield and increase soil fertility.Tripathi *et al*. (2011)found that the addition of sulphur increased the yield of lentil significantly over the control.

Quddus *et al.* (2011) carried out an experiment in Calcareous Low Ganges River Floodplain Soil (AEZ 12) during Kharif I of two years to evaluate the effect of zinc (Zn) and boron (B) on the yield and yield contributing characters of mungbean (*Vigna radiata*L. Wilczek) and to find out the optimum dose of Zn and B for yield maximization. Results showed that the combination of $Zn_{1.5}B_{1.0}$ produced significantly higher yield of 3058 kg ha^{-1} and 2631 kg ha^{-1}, in the year 2008 and 2009, respectively. The lowest yield of 2173 kg ha^{-1} and 1573 kg ha^{-1}, were found in control (Zn_0B_0) combination in both cases. They found that the combined application of zinc and boron were superior to their single application in both the years. Therefore, the combination of $Zn_{1.5}B_{1.0}$ considered as suitable dose for mungbean cultivation in Bangladesh. But from regression analysis, the optimum treatment combination was $Zn_{1.87}$ $B_{1.24}$ kg ha^{-1} for Madaripur.

Barua *et al.* (2011) studied to examine the effects of mimosa (*Mimosa invisa*) compost (M) and phosphorus (P) on the yield and yield components of lentil variety BARI Masur

6. Two factors were: a) *Mimosa invisa* compost and b) phosphorus fertilizer. *Mimosa invisa* compost were used in four rates- 1 (M_1), 5 (M_2), 10 (M_3) and 15 (M_4) t ha^{-1}. Five rates of phosphorus fertilizer were: 'no' phosphorus (P_0), 25% RDP (P_1), 50% RDP (P_2), 75% RDP (P_3) and 100% recommended dose phosphorus (TSP @ 85 kg ha^{-1}) (P_4). They found the highest seed yield (1435.33 kg ha^{-1}) with M_2 treatment (5 t ha^{-1}) and the lowest seed yield (1220 kg ha^{-1}) with M_4 treatment (15 t ha^{-1}). The highest seed yield (1464.17 kg ha^{-1}) was observed with P_4 treatment (100% RDP) and the lowest was observed with P_0 treatment. The interaction effect of *Mimosa invisa* compost and phosphorus on the yield of lentil was also significant. The highest seed yield was observed (1630 kg ha^{-1}) in $M_2 \times P_4$ treatment and the lowest was in $M_3 \times P_0$ treatment (1000 kg ha^{-1}).

2.1.6. Effect of Nutrient Management Practices and Intensive Cropping on Nutrient Content and Uptake by Crops

The nutrient uptake of grain and straw of different crops increased with increasing application of that particular nutrient. Jokela and Randall (1989) observed in their field study that plant uptake of N was increased by N application. Nitrogen uptake by grain was always higher than other parts of the crops.

2.1.6.1. Nutrient Content and Uptake by Jute

Mazumdar *et al.* (2014) reported that the effect of purely chemical fertilizer treatment was significantly different from the other treatments. The uptake of potassium by jute varied from 37.3 to 120.5 kg ha^{-1} under different treatments. Uptakes of K by component crop were significantly less under control and imbalanced use of fertilizer than under balanced use of fertilizer. The highest K uptake was found with 150% NPK, followed by 100 % NPK+FYM and the lowest K uptake by jute was observed in the control plot.

Alam *et al.* (1994) reported that the accumulation of S in jute enhanced with N application. The addition of increasing levels of N increased S content up to 200 kg N ha^{-1} in root, 150 kg N ha^{-1} in bark, 100 kg N ha^{-1} in stem and 150 kg N ha^{-1} in leaves and further increase of N a decline in this trait was noted, perhaps due to growth dilution effect. Dash *et al.* (2010) reported that the Fe and Mn content in jute bark due to application of N through organic sources improved significantly, as organic materials supply chelating agents, which helps in maintaining the solubility of micronutrients including Fe and Mn.

Alim (2003) conducted two sets of experiments to evaluate the impact of N and K application on growth, yield and nutrient uptake by jute. The application of nitrogen fertilizer significantly increased the content and uptake of nutrients in different plant parts. The highest total content and uptake of nitrogen, phosphorus and sulphur were recorded with 200 kg N ha^{-1}. On the other hand, the highest potassium uptake (340.49 kg ha^{-1}) by different parts of plant was recorded with 100 kg K ha^{-1} application. The highest total uptake of nitrogen, phosphorus and sulphur were found with 150 kg K ha^{-1} treatment.

Brahmachari and Mondal (2000) conducted an experiment during 1994-1996 to evaluate crop productivity and soil fertility building under jute (*C. olitorius*), Rice - Rape (*B. campestris* Var. oleifera) cropping sequence. The maximum N, P and K uptake by jute was recorded with NPK + FYM treatment than that of other treatments.Messey and Winsor (1980) observed that total uptake of K increased with the increment of N supply.

Maitra *et al.* (2000) conducted a pot culture experiment on jute (*Corchorus olitorius* cv. JRO 7835) grown in Lateritic soil of Panagrah, West Bengal, India to study the effect of K and Zn application on dry matter production and their uptake by jute crop fibre and wood. Total K uptake increased significantly with the application of K and Zn individually. Uptake of K by both bark and wood was also significant due to application of K alone. But the effect of Zn alone and K x Zn interaction on fibre and wood did not show any significant results. Sarkar *et al.* (2000) also found increased uptake of K with increased potassium supply.

2.1.6.2. Nutrient Content and Uptake by Rice

Saleque *et al.* (2005) found that the total P uptake by rice ranged from 9.3 to 23.3 kg ha^{-1} with N and from 6.3 to 13.0 kg ha^{-1} without N. Panauallah *et al.* (2005) estimated that majority of potassium uptake by straw and the proportion in grain of rice varied from 11% to 29%.Hasan *et al.* (2009) found from a 29 years long experiment that the N and P content in grain and straw of rice were increased with the combined application of N, P, K, S and Zn. The total uptake of N, P, K and S increased with the application of N, P, K, S and Zn in different combinations. Jagadeeswari *et al.* (2001) reported that potassium uptake by rice grain increased due to the application of cow dung along with NPK fertilizers.Ritamoni *et al.* 1999 found that the application of organic sources of nutrient significantly increased the uptake of NPK by rice grain.

Baskar (2003) conducted a field experiment to study the effect of integrated use of inorganic fertilizers and FYM or green leaf manure (GLM) on uptake and nutrient use efficiency of rice – rice system and found that continuous use of organics (FYM / GLM) along with inorganic fertilizers increased nutrient uptake and nutrient use efficiency of major nutrients than did the inorganic fertilizers. Roul and Sarawagi (2005) found that N content and uptake by rice were significantly higher under combined application of chemical fertilizer and manure than only chemical fertilizer or only manure.Sengar *et al.* (2000) reported that the application of cow dung along with chemical fertilizers resulted in markedly higher uptake of phosphorus.

Mohanty*et al.* (2013) carried out an experiment during kharif seasons of 2007-08 and 2008-09 and found that the application of $1/3^{rd}$ recommended dose (RD) of N each through chemical fertilizer; FYMand *Azolla* registered the higher grain and straw yield of rice as compared to 100% recommended dose of fertilizer and control. This was at par with the application of 50% RDN as chemical fertilizer + 50% RDNeither as dhaincha *or Azolla*. N and P uptake by rice was highest with the use of $1/3^{rd}$N each as chemical fertilizer, FYM and *Azolla*, but higher K uptake was reported with application of 50%Nas chemical fertilizer and 50% Nas dhaincha.

Sarker*et al.*(2015) found that the N content in grain and N and K content in straw were also showed similar trend. Sulphur content in grain and P, S content in straw were higher in 75% of recommended dose of S + 5 t PM ha^{-1} compared to other fertilizer treatments. Lowest N and S content in grain and N, P, K, S content in straw were found from the treatment using poultry manure only.Sanchez (1976) reported that organic manure supplied most of the sulphur to plants.Rashid (2009)reported that the application of cow dung along with chemical fertilizers resulted in markedly higher uptake of S by rice that the other combinations.

Islam *et al.* (2014) reported that the N content and uptake by the grain and straw were differed significantly due to different treatments and maximum uptake was recorded with the application of 75% recommended dose of nitrogen (RDN) and green manure incorporated at 50 DAS. In a field experiment with Boro-Fallow-T. aman cropping pattern in Old Brahmaputra Floodplain Soil of Bangladesh, Islam*et al.* (2014) found that the NPKS uptake by T. aman rice supported the dominant performances of $T_{4.2}$ (100% NPS + 50% K + 25% boro rice straw removed). The results suggested that it is possible to reduce K mining from soils as well as to reduce the rate of K fertilizer application, substituting by incorporation of rice straw residues in soil system.

Bhuiyan*et al.* (2011) conducted an experiment with Wheat-T. aus/Mungbean-T. aman cropping pattern and found that the N, P, K, S, Zn, and B uptake by T. aus/Mungbean remarkably increased with increasing supply of nutrients. The highest uptake of N, P, K, S, Zn, and B by the crops was noted in the treatment T_3 (NPKSZnB) that received HYG fertilizers in T. aus rice. The application of cow dung along with chemical fertilizers resulted in markedly higher uptake of nutrients.

Hossain*et al.* (2011) evaluated the effect of B in terms of mineral nutrients (N, P, K, S, Zn, and B) uptake through an experiment conducted for three years in calcareous soil. Boron and N concentrations in grain and stover of rice were significantly increased with increased the rate of B application. In case of P, S and Zn, the concentrations were significantly increased but in case of K, it remained unchanged in stover. The grain B concentration increased from 19.96 µgg^{-1} in B control to 45.99 µg g^{-1}and 51.29 µg g^{-1}due to application of 1 kg and 2 kg Bha^{-1}, respectively.

Mollah *et al.* (2010) conducted a field experiment to evaluate the different brands of zinc fertilizer produced and marketed in different areas of Bangladesh and their effect on nutrients content in rice (BRRI dhan32). Among the nutrients, the content of N, S and Ca in grains and straw did not vary significantly, but the contents of P, K, Na, Mg, Zn, Cu, Fe and Mn in grain and straw varied significantly due to the application of different brands of zinc fertilizer. The nutrient content in grain was the highest N, P, K, Na, Ca, Mg, S are 1.28, 0.04, 0.20, 0.08, 0.16, 0.32, 0.19% and Zn, Cu, Fe, Mn are 10.77, 8.96, 185.30, 61.33 µg g^{-1}, respectively. On the other hand, the highest content of N, K, Na, Ca, S are 0.71, 5.04, 0.08, 0.37, 0.21 % was found in straw, respectively and Zn, Cu, Fe, Mn are 56.65, 55.79, 263.7, 548.8 µg g^{-1}, respectively. It is apparent that Zn^{-2} induced highest accumulation of P, Zn, Cu and Mn in rice grain, whereas in straw this brand induced the highest concentration of N, Fe and Mn.

2.1.6.3. Nutrient Content and Uptake by Mustard

Hossain *et al.* (2011) conducted an experiment for three years to find out the optimum rate of B application for maximizing nutrient uptake and yield of mustard in calcareous soil. The mustard crop (*B. napus* group) cv. BARI Sarisha-8 responded significantly due to B application at 0, 1, and 2 kg ha^{-1}. Boron and N concentrations of grain and stover were significantly increased with increased rate of B application. In case of P, S, and Zn, the concentrations were significantly increased but in case of K, it remained unchanged in stover. The grain B concentration increased from 19.96 µg/g in B control to 45.99 µg/g and 51.29 µg/g due to application of 1 kg and 2 kg B/ha, respectively.

Zamil *et al.* (2004) carried out a pot experiment to find out the effects of different animal manure on yield, quality and nutrient uptake by mustard cv. Agrani. The experiment comprised of two levels of cage system poultry manure, deep litter system poultry manure, cow dung and bio-gas slurry viz. 10 and 20 t ha^{-1}, one control and one chemical fertilizer @ recommended dose. In straw and seed the highest uptake of N, P, K, Ca, Mg and S was obtained from cage system poultry manure @ 20 t ha^{-1}. The overall results suggest that cage system poultry manure @ 20 t ha^{-1} gave best performance among the parameters studied.

Krishna and Singh (1992) reported from a field trials in a Rabi season 1982-84 at Kanpur, Uttar Pradesh that *Brassica juncea* cv, Varuna, Puna Bold and RLM-514 were given 0, 15, 30 or 45 kg $ZnSO_4$ ha^{-1}. Seed yield increased with up to 30 kg $ZnSO_4$ highest in Varuna. Zn application increased Zn content and uptake and decreased the content and uptake of P and S in seeds and stover in both years.

2.1.6.4. Nutrient Content and Uptake by Lentil

Ganeshamurthy (1996) conducted a field experiment and found that the different levels of sulphur significantly increased the sulphur uptake by grain of lentil. The highest sulphur uptake was found when sulphur was applied at 30kg$ha^{-1}$and the lowest from no sulphur application. The results revealed that with the increase in sulphur level increases the uptake due to high sulphur content and high grain yield.Kundu *et al.*, (2006) reported that the application of phosphatic biofertilizer increased P uptake by the different crops specially lentil crop. Deo and Khaldelwal (2009) reported a positive effect of S and Zn on N absorption by lentil crop. They found that nitrogen uptake by grain and straw of lentil increased due to S and Zn application.Khatun *et al.* (2010) found significant variation among the three test varieties of lentil was observed for nitrogen content and nitrogen uptake, and protein content where the highest concentration of nitrogen was observed in BARI Masur-4 which ultimately gave higher protein yield, while the lowest was in BARI Masur-2.

Upadhyay (2013) carried out a field experiment on alluvial soil to study the effects of sulphur and zinc nutrition on lentil for yield, quality and uptake of nutrients. He observed that the mean uptake of S by grain and straw increased from 4.2 to 7.3 and from 3.6 to 6.6 kg ha^{-1}, respectively with the increase of S levels. The uptake of Zn also increased with the levels of Zn from 27.0 to 64.1 and 24.0 to 61.7 g ha^{-1}, respectively. The uptake of N and K increased up to 30 kg S ha^{-1} and 6 kg Zn ha^{-1} level. Phosphorus uptake by straw increased up to 2 kg Zn ha^{-1} followed by reduction at higher levels of Zn. Sarwar (2003) found that the effects of B levels and varieties on uptake of P by grain and stover were statistically significant.

Afzal et al. (2003) foundthat varieties differed significantly for nitrogen uptake bygrain and stover of lentil. BARI Masur-4 showed 4.13% nitrogen, while BARI Masur-3 had 4.08% and BARI Masur-2 had 4.53% nitrogen. Higher nitrogen uptake was associated with higher seed yield.Haque and Khan (2012) conducted a field experiments to evaluate the effects of phosphatic biofertilizer with inorganic or organic sources of P on lentil (*Lens culinaris* Medikus) (var. Binamasur 2), Phosphatic biofertilizer (PB). Phosphatic biofertilizer with 50% P from TSP gave the highest seed and stover yields as well as total P uptake by lentil compared to the 100% P from TSP. The results revealed that 50% inorganic or organic sources of P can be saved by the integrated use of phosphatic biofertilizer for the lentil cultivation in Bangladesh.

2.2. Effect of Intensive Cropping and/or Cropping System on Nutritional Status of Soil

In the recent years, intensive crop cultivation using high yield varieties of crop with imbalanced fertilization has led to mining out scarce native soil nutrients to support plant growth and production, the dominant soil ecological processes that severely affected the fertility status and production capacity of the major soils in Bangladesh. Available data indicated that the fertility of most of our soils has deteriorated over the years (Ali *et al.*, 1997), which is responsible for national yield stagnation and in some cases, even declining crop yields (Cassman *et al.*, 1997).

2.2.1. Effect of Intensive Cropping on Nutritional Status of Soil

Intensive cultivation and growing exhaustive crops have made the soil deficient in macro as well as in micronutrients. The success of any cropping system depends upon the appropriate management of resources including balanced use of manures and fertilizers. Hossain (1991) reported that the cropping pattern and the intensity of cropping are more particularly influenced by the time of onset of the monsoon rains, the amount, time and allocation of rainfall, the incidence of natural calamities such as storms, cyclones and the length of flooding period. Depending on these features, more than 60 variations of cropping patterns are practiced in Bangladesh.

In maize-cowpea cropping system, cowpea has been reported to potentially contribute considerable amounts of nitrogen to succeeding crops (Sanginga *et al.*, 1996). According to Kombiok *et al.*(1997), maize yielded 3 t ha^{-1}more when it followed cowpea than when it followed maize or sorghum in a rotation. Crops grown in rotation affect soil fertility and often have higher yields than those grown in a monoculture (Anderson *et al.*, 1997). Relative to continuous production, cereal yield benefits are realized when cereals are planted in rotation with legumes (Clegg, 1992; Copeland *et al.*, 1993).

Saleque *et al.*(2004) found that increase in cropping intensities enhanced nutrient mining from the soil, because nutrient removal by crops has exceeded annual replacement with fertilizers. Intensive cropping promotes high levels of nutrient extraction from the soil without providing opportunities for natural regenerating processes (Narang *et al.*, 1990). According to Maciaszek *et al.* (1987), the use of legumes in rotation with non-legumes helps to restore soil productivity. However, modern agricultural systems have caused progressive degradation of soil structure and depletion of soil fertility due to reduction in soil organic matter (Masciandaro *et al.*, 1997).

In order to improve the productivity of cropping systems so as to arrest the worsening economic conditions in the country, there is the need to study nutrient dynamics in the various cropping systems. The knowledge of soil fertility variation in different cropping systems provides a strong foundation for sustainable agricultural production (Ranamukhaarachchi *et al.*, 2005). Anderson *et al.*(1997) reported that cropping systems have different effects on soil properties and thereby governing the soil conditions. This is partly due to the nature of nutrient uptake by different crops (BARC, 2012). The present challenge is to sustain soil fertility in cropping systems operating at high productivity.

The productivity per unit area per unit time can be increased by increasing the cropping intensity. This could be achieved by a suitable combination of crops in sequence (Singh*et a1.*, 1980; Hedge and Patil, 1981). Each crop in a multiple cropping system need not give the maximum yield but should be such that the combined yields of all components in the system should give maximum production or return per unit of the cropped area (La1 and Ray, 1976).

After conducting long field trials in four sites Becker and Johnson (2001) observed that increased cropping intensity and reduced fallow duration were associated with yield reduction, which was largest at the sites in the derived savanna (1.48 vs. 1.15) and the bimodal forest zones (1.55 vs. 1.02). Intensification-induced yield loss was about 25% and appeared to be related mainly to increased weed infestation and declining soil quality (about 20% less soil organic C content and N supply). They also found that the reduction in soil organic carbon and N supplying capacity was strongest in the derived savanna zone where N supply explained 35% of the yield gap. Long-term upland rice productivity can thus not be sustained at current intensification practices. Improved management strategies should aim primarily at reducing weed pressure and improving soil organic matter content and N supply.

Mondal*et al.* (2015) conducted an experiment with three cropping patterns with two rice crops as control for increasing cropping intensity and productivity. They found the highest rice equivalent yield (REY) 34.10, 34.02 and 33.36 t ha^{-1} from the CP_2(cropping pattern - 2) in 2011 - 12, 2012 - 13 and 2013 - 14, respectively and it was followed by CP_1 and CP_3.

Shifting cultivation, as practiced by the traditional farmers to restore soil fertility in sustaining cropping can no longer meet up with the increased need for food supply due to high population pressure. The length of fallow period required to replenish the soil to maintain soil productivity has to be shortened. The primary function of soil productivity and fertility restoration through fallow is less effective since intensive cropping is now more common. The use of inorganic fertilizers alone has not been helpful under intensive agriculture because it aggravates soil degradation (Sharma and Mittra, 1991).

In a study carried out on different aspects of green manuring crops, Bhuiyan and Zaman (2014) found that the potential of cowpea (*Vigna unguileata*) was much higher than that of dhaincha (*Sesbania aculeata*), as a green manuring crop, with respect to mineral composition and its influence on rice yield. However, incorporation of the dhaincha green manuring crop in a Boro-T. aman cropping system can save about 70 kg N ha^{-1} yr^{-1} in the long term. They also observed that *Sesbaniarostrata* was superior to other species with respect to biomass production and accumulation. *Sesbania rostrata* was found to be superior to other planting practices and had the ability to supplement almost the entire amount of N in the next crop of rainfed lowland rice.

2.2.2. Effect of Cropping System on Nutritional Status of Soil

To ensure high productivity of cropping systems, there is the need to put in measures aimed at maintaining the fertility of the soil resource base, on which crop production depends. Maintaining innate soil fertility is, therefore, an urgent priority in tropical cropping systems (Arihara, 2000). According to Grant *et al.*(2004), effective nutrient management is a critical part of crop production not only to improve financial returns, but also to maintain soil quality and reduce the likelihood of damage to the environment. Howarth (2005) stated that management of nutrients to maintain productivity and quality of cropping systems is a challenge that must be met through a combination of organic amendments and management of soil organic matter.

Magdoff and Amadon (1980) showed that yearly applications of 66 $kgha^{-1}$ of fresh dairy manure were needed to increase soil organic matter from 5.2 to 5.5 % over the course of 11 years on a land on which silage corn was produced using conventional tillage. Although organic amendments such as crop residues, manure or composts are essential in the sustainability of cropping systems, they cannot prevent nutrient mining entirely (Bationo *et al.*, 1998). The addition of organic amendments corresponds in most cases to a recycling process, which cannot compensate for nutrient exported through crop products. As a result, the use of external inputs such as inorganic plant nutrients is essential requirement for soil productivity.

2.3. Effect of Management Practices and Intensive Cropping on Nutrient Balance

A field experiment was conducted during 2007 and 2008 to find out the optimum nutrient management practice for grain yield, nutrient balance and economics of T. aman rice (Jahan *et al.*, 2015). Twelve nutrient management treatments (with and without CRI) were tested in RCBD with 3 replications. They found that except N and K, remaining nutrient balance like P, S, Zn and B were found positive in case of High Yield Goal (HYG), Moderate Yield Goal (MYG), Integrated Nutrient Management System (IPNS) and Soil Test Based (STB) along with or without Crop Residue Incorporated (CRI) nutrient managements while farmers' practice and control showed negative balance.

Singh*et al.* (2015) carried out an experiment with rice (*Oryza sativa* L.)-based cropping systems in Indo-Gangetic Plains (IGP) to evaluate the site-specific nutrient management (SSNM) option against existing FP (Farmers' Practice) in terms of yield gain, economics, nutrient harvest index, soil fertility, and apparent nutrient balances. After three crop cycles, apparent N and P balances were positive in all the cropping systems and fertilizer treatments; only exception was a negative N balance in chickpea - rice and berseem fodder–rice systems in different fertilizer treatments. The apparent K balances were negative in all the cropping systems irrespective of nutrient management options. But, the magnitude of negative balance was lower in plots received SSNM treatment compared to other nutrient management strategies, indicating a potential for improving yields, nutrient use efficiency and farm profit without deteriorating of soil fertility in different rice based systems in IGP.

Husnain *et al.* (2010) studied to assess the balance of N, P, K, Si, Ca, Mg, and Na in a lowland sawah (rice fields) in the Citarum Watershed, Java, Indonesia. The nutrient balances were estimated as an average of total input minus total output at four study sites. Input parameters were nutrient content derived from fertilizer, irrigation water, and nitrogen fixation, and output parameters were nutrient loss through harvest, drainage water, and denitrification. The results showed a positive balance for N, P, Ca, Mg, and Na; however, K and Si showed a negative balance. The balance values were estimated at 5, 8, 387, 65, 281, -198 and -21 for N, P, Ca, Mg, Na, Si and K, respectively. The decrease in Si and K observed in this study is likely due to the substantial uptake of these nutrients without adequate replenishment through fertilizer.

Rahman *et al.* (2009) carried out a study on integrated nutrient management through chemical fertilizers in combination with organic materials (cow dung and rice straw/bush bean stover) in the Bush bean - T. aus - T. aman cropping pattern over three years to find out a suitable combination for obtaining higher yield of crops. They observed an excess N uptake where N was added as fertilizer only. The apparent balance (nutrient added through manures and fertilizers minus nutrient removed by crops) for both N and K was negative while that for P & K was mostly positive.

Panaullah*et al.* (2007) conducted a field experiment on the rice - wheat (RW) cropping sequence at three locations in Bangladesh with three soil types to detect K deficiency, if any, in rice, wheat, mungbean, and maize, and to compare the FP and STB-based sequences in terms of the K nutrition of those crops and the apparent K balance in soil. The majority of K uptake was in straw and the proportion in grain varied little across sites (range: 11 - 29%). There were large negative apparent K balances in all treatments at all sites (range: - 25 to - 212 kg ha^{-1}), with the greatest at Ishwardi and the smallest at Joydebpur. Soil K balance responded differently to the retention of residues across soils, and positive effects could be observed on clayey soils.

Saha *et al.* (2007) carried out a field trial on integrated nutrient management for a dry season rice (Boro) - green manure - wet season rice (T. aman) cropping system. Five packages of inorganic fertilizers, cow dung (CD), and GM dhaincha (*Sesbania aculeata*) were evaluated for immediate and residual effect on crop productivity, nutrient uptake, soil-nutrient balance sheet, and soil-fertility status. The total P, K, and S uptake (kg ha^{-1}) in the unfertilized plot under an irrigated rice system gradually decreased over the years. The partial nutrient balance in the unfertilized plot (T_1) was negative for all the nutrients. In the fertilized plots, there was an apparent positive balance of P, S, and Zn but a negative balance of N and K. This study showed that the addition of organic manure (CD, dhaincha) gave more positive balances. The application of CD and dhaincha GM along with chemical fertilizers not only increased organic C, total N, available P, and available S but also increased exchangeable K, available Zn, available iron (Fe), and available manganese (Mn) in soil.

Zhao*et al.* (2011) conducted a 3-years field experiment to determine the integrated N input and output in a rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) double - cropping systems in the Taihu Lake region of southern China. The results indicated little N surplus in the soil despite different patterns of N input and output in rice and wheat seasons. Although total N input was higher for rice than wheat, the output was also proportionately higher so that the balance was similar between the two crops. The total annual N input reached up to 606 kg N ha^{-1}, the annual N output was as high as 599 kg N ha^{-1}, of which 52% was lost into the environment, leaving little N in the soil. These results demonstrated that the overwhelming majority of N input did not remain in the soil but rather was quickly emitted. Proper practices are imperative to optimize the N balance and minimize N loss.

Liu *et al.* (2011) conducted a field experiment to study the nutrient balance between N, P, and K in flue-cured tobacco production under the effects of different preceding crops including rape, wheat, barley, and green manure planting. Overall, there existed significant differences in the soil nitrogen availability, tobacco plant dry matter accumulation, plant uptake of N, P and K, residual amounts of soil N, P, and K, apparent soil N loss, and apparent soil P and K surplus during tobacco growth period under different preceding crops planting. The N and K uptake by tobacco plant were all the highest, followed by under preceding rape planting, and under preceding barley or wheat planting. The P uptake by tobacco plant was also obviously higher under the preceding green manure or rape planting than under preceding barley or wheat planting. It was suggested that an appropriate adjustment should be made on the fertilization rates of N, P, and K for tobacco production based on the preceding crops, i.e., lesser N application when the preceding crop was green manure or rape, and lesser application of P and K when the preceding crop was wheat or barley.

The literature reviewed suggests that the effective nutrient management is a critical part of crop production not only to maintain soil fertility, but also to improve financial returns. Continuous cropping is most often characterized by low soil fertility which is more pronounced in this region (AEZ 12). Maintenance of soil fertility is a prerequisite for long-term sustainable agriculture where chemical fertilization and organic manuring (cow dung, poultry manure and mustard oil cake) can play a vital role in the sustenance of soil fertility and crop production. The nutrient balances in soils, which are the equivalent amount of the yearly nutrient uptake by crops in an intensive cropping pattern, may be achieved by applying organic manures in combination with chemical fertilizers.However,there is a gap in literature regarding systematic study or monitoring of soil organicmatter, N, P, K, S, Ca, Mg, etc. as affected by specific nutrient management practices and nutrient balances under intensive cropping in AEZ12.

CHAPTER 3
MATERIALS AND METHODS

The methodological procedure of a scientific research includes research design, selection of study area, sampling procedures, analytical techniques and how to interpret the data found from the analyses and field by following scientific techniques. Field experiments were conducted at two different locations during 2013 to 2015. Two cropping patterns i.e. Jute-T. aman –Mustard and Jute-T. aman – Lentil were followed in this research for two experimental sites. Samples of soils, plants and respective yield parameter data were collected from each experimental plot and analyzed.

3.1. Study Area

The research fields were situated in Paranpur and Tilchara area under Kashiani upazila of Gopalganj district in Dhaka division of Bangladesh (Figure 3.1). The experimental locationswere selected through field visit.Then soilseries were identified by using the technical assistance of Soil Resource Development Institute (SRDI), Barisal.The Paranpur site lies between 23°10'59.8" N latitude and 89°46'02.2" E longitude and Tilchara site lies between 23°10'47.3" N latitude and 89°46'37.8" E longitude having a mean elevation of 8.3 m above mean sea level (SRDI, 2002).

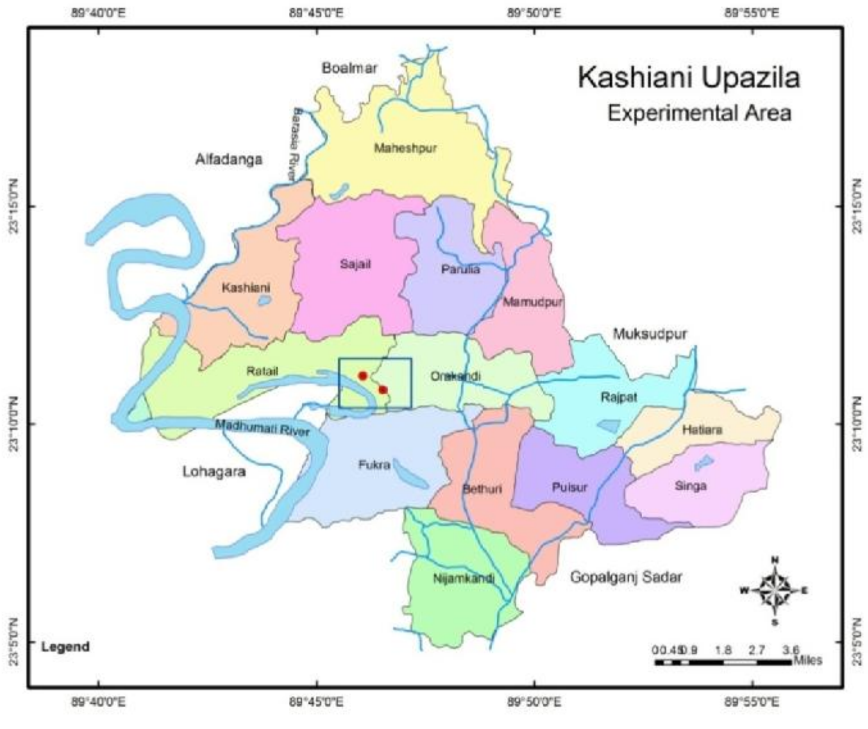

Figure 3.1. Location of the experimental site in Kashiani upazila.

3.2. Climate and Weather Conditions

The climate of the experimental area issub-humid tropical. The rainy season (monsoon) runs from May to October andabout 75% total rainfall occurs during this period. October and November months are characterized as post-monsoon season with some amount of rainfall. Driest and coolest winter season starts from the month of December and ends in February. In 2015, the average annual temperature was 26.4°C and total annual rainfall was 1827 mmin Gopalganj district (Table 3.1). The driest months were November, December, January, February and March. No precipitation occurredin these months. The greatest amount of precipitation occurred in July with a total of 540 mm. Maywas the warmest month with an average temperature of 29.9°C. The lowest average temperature in the year occurred in January, when it was 18.8°C (BBS, 2016).

Table 3.1. Monthly rainfall and temperature recorded in 2015.

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Rainfall (mm)	6	21	2	159	147	347	540	304	215	80	0	6
°C (min)	13.0	15.4	18.7	22.6	25.2	26.2	26.0	26.7	26.2	23.8	19.0	15.1
°C (max)	24.5	28.5	32.7	33.2	34.5	33.0	32.0	32.6	33.4	32.9	30.6	25.9
°C (avg.)	18.8	22.0	25.7	28.0	29.9	29.7	29.1	29.7	29.8	28.4	24.9	20.5

Source:BBS, 2016.

3.3. Physiography

The region has a typical meander floodplain landscape of broad ridges and basins. Relief alongside of the rivers crossing the region generally is somewhat irregular, comprising broad and narrow ridges, inter-ridge depressions and cut-off channels. Differences in elevation between ridge tops and basin centres are generally in the range of 3-5 m (UNDP-FAO, 1988). The vast plain is washed by the river Madhumoti. Tropical monsoon rains drench the land and the rivers. The plainland lies almost at sea level. The topography, however, variable and the area can be divided into the following classes i.e. highland, medium highland, medium lowland, lowland and very lowland.

3.4. Drainage

In most part of the region, the highest part of ridges stands above normal flood-level. However, they generallybecome wet during periods of heavy monsoon rainfall when the surrounding land is flooded and they may be submerged for a short period during exceptionally high floods. Adjoining middle parts of ridges are shallowly flooded at the peak of normal floods. Basins are moderately deeply or deeply flooded. The region has a high proportion of soils with clay topsoil which causing water-levels to rise rapidly in basin centres(UNDP-FAO, 1988).

3.5. Agro-ecological Zone

The present study was conducted in the AEZ-12 (Low Ganges River Floodplain), comprises the eastern half of the Ganges River Floodplain which is low-lying than the western half. The boundary between this region and Barind Tract is sharp. Soils of the region are silt loams and silty clay loams on the ridges and silty clay loams to heavy clays on lower sites. General soil types predominantly include Calcareous Dark Grey and Calcareous Brown Floodplain soils. Organic matter content is low in ridges and moderate in the basins. Soils are calcareous in nature having neutral to slightly alkaline reaction. General fertility level is medium (UNDP-FAO, 1988).

3.6. Soil Series

The soils of the experimental site belong to the Sara series and Gopalpur series of the Calcareous Dark Grey Floodplain Soils (Typic Haplaquepts) under the order Inceptisols in the USDA Soil Taxonomy (Hussain,1982). The morphological and taxonomical characteristics of the experimental sites are shown in Table 3.2.

Table 3.2. Correlation of soil series with different classification systems.

Soil series	**AEZ**	**General Soil Types**	**FAO-UNESCO Soil Sub-unit**	**USDA Soil Taxonomy (Sub-group)**	**Land Type**	**Location**
Sara	Low Ganges River Floodplain	Calcareous Dark Grey Floodplain Soils	Chromi-Clacaric Gleysols	Typic Haplaquepts	High	Village: Paranpur, Union: Ratail, Upazila: Kashiani, District: Gopalganj.
Gopalpur	Low Ganges River Floodplain	Calcareous Dark Grey Floodplain Soils	Chromi-Calcari Gleysols	Typic Haplaquepts	Medium high	Village: Tilchara, Union: Orakandi, Upazila: Kashiani, District: Gopalganj.

Source: Hussain, 1982.

3.6.1. Sara Series:

Sara series includes moderately well and poorly drained, pale-brown calcareous loam. These soils are developed in Ganges River Alluvium. Vegetable and sugarcane production may be increased by frequent irrigation.

3.6.2. Gopalpur Series:

Gopalpur series includes intermittently and seasonally shallowly flooded, imperfectly drained pale brown calcareous clay loam. These soils are developed in Ganges river alluvium. Soil moisture in dry season is medium and wetness in rainy season. It is slightly alkaline.

3.7. Soil Characteristics

The soils of the study area comprised of Ganges River Alluvium parent materials and have considerable variations in morphological, physical and chemical characteristics. The soils are in general slightly alkaline, grey and moderately drained. The Gopalpur series soils in general is seasonally flooded and Sara series soils is over normal flood level (SRDI, 2002).

Table 3.3. Physical and chemical characteristics of the initial soil of experimental fields.

Characteristics	Sara series	Gopalpur series
Physical Characteristics		
Sand (%)	26.59	22.81
Silt (%)	47.97	41.75
Clay (%)	25.44	35.44
Textural class	Loam	Clay Loam
Bulk density (gcm^{-3})	1.33	1.46
Particle density (gcm^{-3})	2.67	2.70
Total Porosity (%)	50.19	45.93
Field Soil Moisture Content (%)	17.3	21.4
Hydraulic Conductivity (mm/h)	12.3	11.2
Chemical Characteristics		
pH	7.71	7.46
CEC (cmol kg^{-1} soil)	14.68	24.45

Organic Matter (%)	1.23	1.52
Total Nitrogen (%)	0.091	0.119
Carbon to Nitrogen Ratio (C : N)	10.14	9.78
Available P (μgg^{-1})	9.46	10.35
Available S ($\mu g\ g^{-1}$)	14.18	17.47
Available B ($\mu g\ g^{-1}$)	0.816	1.182
NH_4OAc extractable K (cmol kg^{-1} soil)	0.153	0.235
NH_4OAc extractable Ca (cmol kg^{-1} soil)	7.13	9.97
NH_4OAc extractable Mg (cmol kg^{-1} soil)	0.49	1.07
NH_4OAc extractable Na (cmol kg^{-1} soil)	0.053	0.092
DTPA extractable Fe ($\mu g\ g^{-1}$)	41.03	33.98
DTPA extractable Mn ($\mu g\ g^{-1}$)	26.91	20.76
DTPA extractable Zn ($\mu g\ g^{-1}$)	0.734	0.962
DTPA extractable Cu ($\mu g\ g^{-1}$)	2.51	2.62

3.8. Cropping History of the Experimental Field

The productive potential of the experimental field can be judged from its cropping history. The detail account of the cropping history of experimental field prior to the present experiment is presented in Table 3.4.

Table 3.4. Cropping history of the experimental fields.

Years	Sara Series (Paranpur)			Gopalpur Series (Tichara)		
	Kharif-I	Kharif-II	Rabi	Kharif-I	Kharif-II	Rabi
2006-07	Jute	-	Lentil	Jute	T.aman	Lentil
2007-08	Jute	-	Blackgram	Jute	-	Mustard
2008-09	Jute	-	Khesari	Jute	-	Lentil
2009-10	Jute	-	Mustard	Jute	T.aman	Khesari
2010-11	Jute	-	Lentil	Jute	T.aman	Khesari
2011-12	Jute	T.aman	Mustard	Jute	-	Mustard
2012-13	Jute	-	Khesari	Jute	-	Lentil

3.9.Cropping Season and Pattern

Gopalganj has favourable temperature range for crop cultivation throughout the year because of geographical location. On the basis of cultural methods, the whole of the crop-growing period is divided into two main seasons, namely Kharif (Kharif I and Kharif II) and Rabi. In 2014, the net cropped area of Kashiani upazila was about 22,400 hectare. Cropping patterns were single cropped(24.20%), double cropped(55.94%) and triplecropped land (19.87%)(Kashiani Upazila Report, 2014). The dominant cropping pattern is arranged in Table 3.5.

Table 3.5. The dominant cropping pattern with net covered area of Kashiani upazila.

Sl. No.	Cropping Pattern	% of Net Covered Area
1.	Rice (Boro) - Fallow–Fallow	46.41
2.	Rice (Boro) - B. aman–Fallow	13.92
3.	Kheshari – Fallow - B. aman	12.1
4.	Kheshari+Sesame – Fallow - B. aman	8.05
5.	Kheshari+Mustard – Fallow - B. aman	6.31
6.	Lentil – T. aman – Fallow	2.26
7.	Lentil – Jute - B. aman	1.52
8.	Wheat – Jute – B. aman	3.26
9.	Onion - Jute – Fallow	1.09
10.	Sugarcane – Sugarcane – Sugarcane	1.52
11.	Vegetable – Vegetable – Vegetable	1.09
12.	Others	2.39

Source: Kashiani Upazila Report, 2014

The cropping intensity (%) that found in Kashiani upazila is 195.67%. The average cropping intensity of 203.44% in Ratail Block (highland) representing Sara series and 164.56% in Tilchara Block (medium highland) representing Gopalpur series (Kashiani Upazila Report, 2014).

3.10. Nutrient Content of Manures

The applied cow dung (CD), poultry manure (PM) and mustard oilcake (OC) were locally collected.Initially the requirement of organic manures was estimated and whole manures were collected from local sources and were mixed thoroughly. Before application of cow dung, poultry manure and oilcake, composite sample of each manure were taken for chemical analysis.The nutrient content of cow dung, poultry manure and oilcakeis shown in Table 3.6.

Table 3.6. Nutrient content of cow dung, poultry manure and oilcake (air dried sample).

Manure	Nutrient Content								
	C (%)	**N (%)**	**P (%)**	**S (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**Zn («g g^{-1})**	**B («g g^{-1})**
Cow Dung (CD)	13.26	1.63	0.26	0.13	1.04	3.67	0.27	124.82	27.24
Poultry Manure (PM)	12.09	1.44	0.87	0.41	1.84	6.86	0.38	340.31	49.94
Oil Cake (OC)	37.40	5.18	0.74	0.78	0.72	3.82	0.43	67.39	24.97

3.11. Experimental Details

3.11.1. Cropping Patterns and Crops

Two cropping patterns namely Jute - T. aman - Mustard and Jute - T. aman - Lentil were included in this experiment. The Jute - T. aman - Mustard cropping pattern in Sara series and Jute - T. aman - Lentil cropping pattern in Gopalpur series were practiced for a period of two years. Four crops jute, rice, mustard and lentil were included in these patterns. Crops were grown under rainfed and irrigated conditions. The crops of the cropping system were Jute, T.aman, Mustard and Lentil.

3.11.2. Experimental Design and Layout

Two experimental sites were used for implementing two cropping patterns. Sara series based experimental site was selected for Jute-T.aman-Mustard cropping sequence and Gopalpur series based experimental site was utilized for Jute-T.aman-Lentil cropping sequence.The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each treatment. Based on the farmers' practice, recommended doses and soil test based dose as chemical fertilizers alone or in combination with recommended organic manures, eleven combinations of treatment consisting of six types of chemical fertilizers and three types of organic manures were used in the experiments (Table 3.7). Different quantities of nutrients and manures were applied under the treatments for the selected crops produced in soils of Sara and Gopalpur series(Tables 3.8 and 3.9). The field experiment was set up on April 7, 2013 and continued up to February 25, 2015.

Table 3.7. Treatment combinations of different fertilizers.

Treatment	Fertilizer treatments and rates
T_0	Control (No fertilizer or manure)
T_1	Chemical fertilizers N, P, K & Zn applied by farmers
T_2	Chemical fertilizers N, P, K & Zn applied by farmers + Recommended S & B
T_3	75% of chemical fertilizers N, P, K & Zn applied by farmers + 75% of recommended S & B + Cow dung (5 t ha^{-1})
T_4	75% of chemical fertilizers N, P, K & Zn applied by farmers + 75% of recommended S & B + Recommended poultry manure (3 t ha^{-1})
T_5	75% of chemical fertilizers N, P, K & Zn applied by farmers + 75% of recommended S & B + Recommended mustard oil cake (2 t ha^{-1})
T_6	Recommended fertilizer nutrients N, P, K, S, Zn & B
T_7	75% of recommended fertilizer nutrients N, P, K, S, Zn & B + Recommended cow dung (5 t ha^{-1})
T_8	75% of recommended fertilizer nutrients N, P, K, S, Zn & B + Recommended poultry manure (3 t ha^{-1})
T_9	75% of recommended fertilizer nutrients N, P, K, S, Zn & B + Recommended mustard oilcake (2 t ha^{-1})
T_{10}	Treatment based on soil analysis

Table 3.8. Crop and treatment based applied amount of nutrients and manures for Sara series.

Treatment	Sara Series								
	N	P	K	S	Zn	B	CD	PM	OC
	(kg ha^{-1})						(t ha^{-1})		
	Kharif-I: Jute								
T_0	-	-	-	-	-	-	-	-	-
T_1	34.36	29.88	37.35	-	3.14	-	-	-	-
T_2	34.36	29.88	37.35	10.74	3.14	-	-	-	-
T_3	25.77	22.41	28.01	8.05	2.35	-	5.00	-	-
T_4	25.77	22.41	28.01	8.05	2.35	-	-	3.00	-
T_5	25.77	22.41	28.01	8.05	2.35	-	-	-	2.00
T_6	111.00	10.00	42.00	13.00	-	-	-	-	-
T_7	83.25	7.50	31.50	9.75	-	-	5.00	-	-
T_8	83.25	7.50	31.50	9.75	-	-	-	3.00	-
T_9	83.25	7.50	31.50	9.75	-	-	-	-	2.00
T_{10}	91.67	13.60	15.89	-	3.34	-	-	-	-
	Kharif-II: T.aman								
T_0	-	-	-	-	-	-	-	-	-
T_1	68.72	29.9	37.4	-	3.14	-	-	-	-
T_2	68.72	29.88	37.35	6.29	3.14	-	-	-	-
T_3	51.54	22.41	28.01	4.72	2.35	-	5.00	-	-
T_4	51.54	22.41	28.01	4.72	2.35	-	-	3.00	-
T_5	51.54	22.41	28.01	4.72	2.35	-	-	-	2.00
T_6	90.00	10.00	18.00	8.00	1.00	-	-	-	-

T_7	67.50	7.50	13.50	6.00	0.75	-	5.00	-	-
T_8	67.50	7.50	13.50	6.00	0.75	-	-	3.00	-
T_9	67.50	7.50	13.50	6.00	0.75	-	-	-	2.00
T_{10}	73.33	13.40	23.33	-	1.33	-	-	-	-
	Rabi: Mustard								
T_0	-	-	-	-	-	-	-	-	-
T_1	17.18	28.88	37.35	-	-	-	-	-	-
T_2	17.18	28.88	37.35	13.33	0.58	1.00	-	-	-
T_3	12.89	22.41	28.01	10.00	0.44	0.75	5.00	-	-
T_4	12.89	22.41	28.01	10.00	0.44	0.75	-	3.00	-
T_5	12.89	22.41	28.01	10.00	0.44	0.75	-	-	2.00
T_6	90.00	27.00	16.00	15.00	1.00	1.00	-	-	-
T_7	67.50	20.25	12.00	11.25	0.75	0.75	5.00	-	-
T_8	67.50	20.25	12.00	11.25	0.75	0.75	-	3.00	-
T_9	67.50	20.25	12.00	11.25	0.75	0.75	-	-	2.00
T_{10}	110.00	30.60	23.33	-	2.22	-	-	-	-

CD – Cow dung, PM – Poultry Manure and OC – Oil cake

Table 3.9. Crop and treatment based applied amount of nutrients and manures for Gopalpur series.

Treatment	Gopalpur Series								
	N	**P**	**K**	**S**	**Zn**	**B**	**CD**	**PM**	**OC**
	(kg ha^{-1})						**(t ha^{-1})**		
	Kharif-I: Jute								
T_0	-	-	-	-	-	-	-	-	-
T_1	34.36	29.88	37.35	-	3.14	-	-	-	-
T_2	34.36	29.88	37.35	10.74	3.14	-	-	-	-
T_3	25.77	22.41	28.01	8.05	2.35	-	5.00	-	-
T_4	25.77	22.41	28.01	8.05	2.35	-	-	3.00	-
T_5	25.77	22.41	28.01	8.05	2.35	-	-	-	2.00
T_6	111.00	10.00	42.00	13.00	-	-	-	-	-
T_7	83.25	7.50	31.50	9.75	-	-	5.00	-	-
T_8	83.25	7.50	31.50	9.75	-	-	-	3.00	-
T_9	83.25	7.50	31.50	9.75	-	-	-	-	2.00
T_{10}	88.9	13.98	-	-	3.27	-	-	-	-
	Kharif-II: T.aman								
T_0	-	-	-	-	-	-	-	-	-
T_1	68.72	29.9	37.4	-	3	-	-	-	-
T_2	68.72	29.88	37.35	6.29	3.14	-	-	-	-
T_3	51.54	22.41	28.01	4.72	2.35	-	5.00	-	-
T_4	51.54	22.41	28.01	4.72	2.35	-	-	3.00	-
T_5	51.54	22.41	28.01	4.72	2.35	-	-	-	2.00
T_6	90.00	10.00	18.00	8.00	1.00	-	-	-	-
T_7	67.50	7.50	13.50	6.00	0.75	-	5.00	-	-
T_8	67.50	7.50	13.50	6.00	0.75	-	-	3.00	-
T_9	67.50	7.50	13.50	6.00	0.75	-	-	-	2.00
T_{10}	71.11	1.98	-	-	1.31	-	-	-	-

	Rabi: Lentil								
T_0	-	-	-	-	-	-	-	-	-
T_1	17.18	28.88	37.35	-	-	-	-	-	-
T_2	17.18	28.88	37.35	15.85	0.58	1.00	-	-	-
T_3	12.89	22.41	28.01	11.99	0.44	0.75	5.00	-	-
T_4	12.89	22.41	28.01	11.99	0.44	0.75	-	3.00	-
T_5	12.89	22.41	28.01	11.99	0.44	0.75	-	-	2.00
T_6	20.00	30.00	20.00	18.00	1.00	1.00	-	-	-
T_7	15.00	22.50	15.00	13.50	0.75	0.75	5.00	-	-
T_8	15.00	22.50	15.00	13.50	0.75	0.75	-	3.00	-
T_9	15.00	22.50	15.00	13.50	0.75	0.75	-	-	2.00
T_{10}	21.33	4.95	-	-	2.18	-	-	-	-

CD – Cow dung, PM – Poultry Manure and OC – Oil cake

Fertilizer treatments were randomly distributed in each blockconsisting of 11experimental units (plots). The individual plot was 5 m × 4 m i.e 20 sq. m in size for each treatment. The adjacent block and neighboring plots were separated by 1.5 m and 1.0 m, respectively. The details of the layout are given in Table 3.10 and the plan of layout in Figure3.2 and Figure 3.3.

Table 3.10. Details of the layout plan of the experiments.

Experimental design	Randomized complete block design
Number of replication	3
Treatment combination	11
Number of experimental sites	2
Total number of plots	33 x 2
Gross plot size	6.0 m x 5.0 m
Net plot size	5.0 m x 4.0 m
Width of replication border	1.5 m
Width of plot border	0.5 m
Width of main irrigation channel	0.75 m
Width of sub irrigation channel	0.5 m

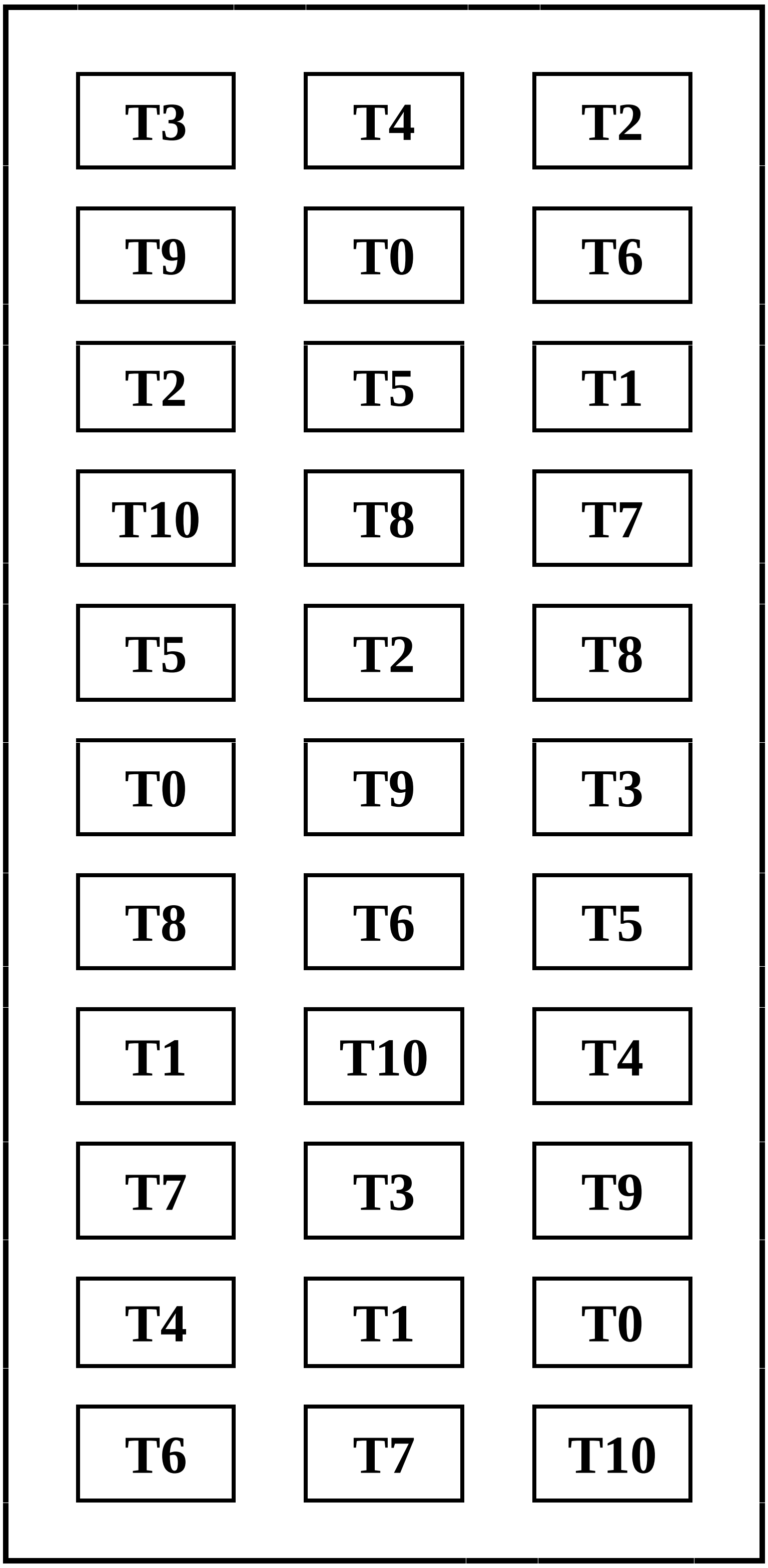

Figure 3. 2. Experimental layout for Jute - T. aman - Mustard cropping pattern (Sara series).

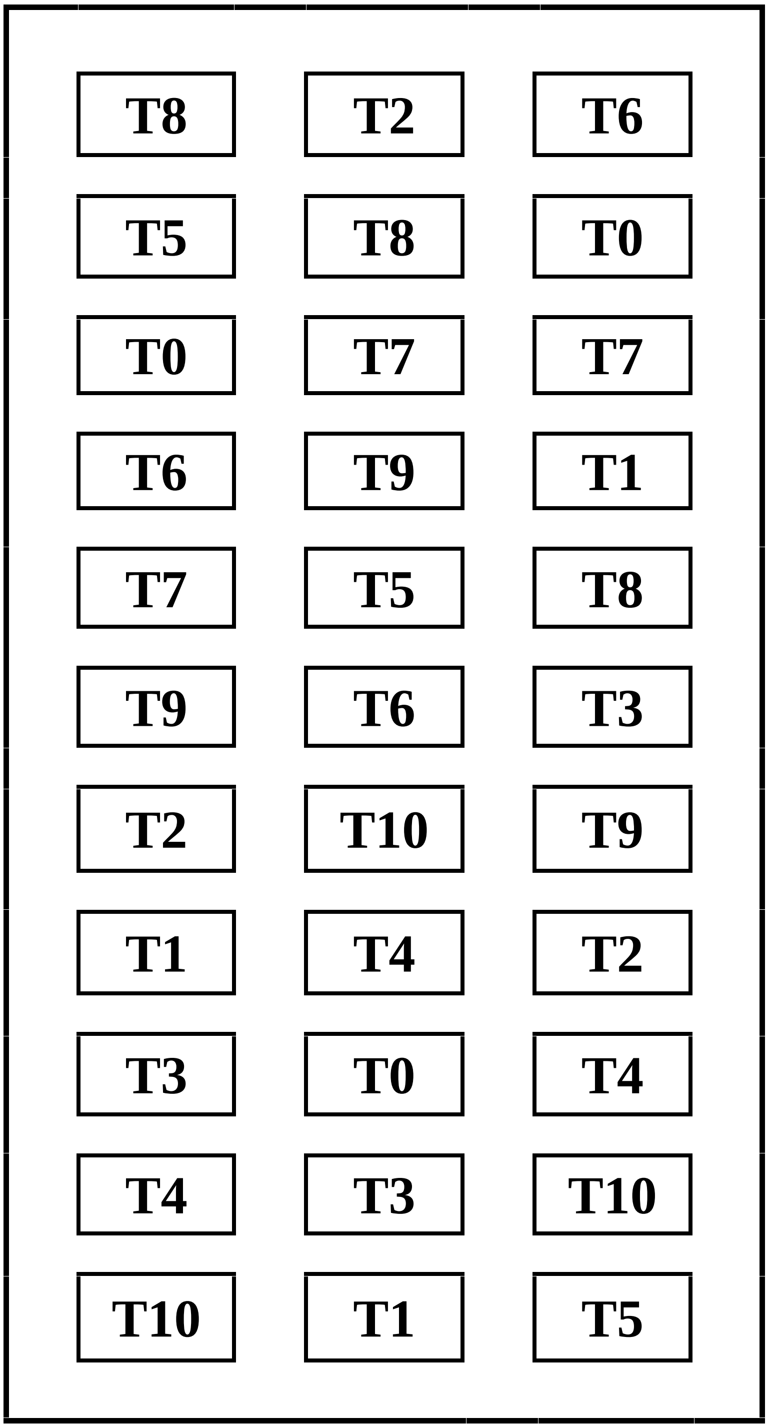

Figure 3.3. Experimental layout for Jute - T. aman - Lentil cropping pattern (Gopalpur series).

3.12.Cultural Operation for Crop Production

3.12.1. Crop Varietiesunder Study

Varieties of tested crops were selected by considering the soil, topography, hydrology, suitability, social acceptability and economic viability of individual crop and cropping sequences in the study area. The crop varieties used in this study were jute (*Corchorus olitorius*L.*)* cv. BJRI Tossa-2, rice T.aman*(Oryza sativa* L.) cv. BRRI dhan39, mustard (*Brassica napus* L.) cv. Rai-5 and lentil (*Lens culinaris* L.) cv. BARI Masur-2 collected from the local seed dealers. Crop varieties used in the systems and their average yield are furnished in Table 3.11.

Table 3.11. Characteristics of crop varieties.

Crops	**Varieties**	**Yield** **(**ton/ha)	**Duration (days)**
Jute (*Corchorus olitorius* L.*)*	BJRI Tossa-2 (O 9897)	4.0-5.0	120-150
Rice (Oryza sativa L.)	BRRI Dhan 39	4.5 (max.)	120-125
Mustard (*Brassica napus*L.)	Rai-5	1.2 - 1.4	90-100
Lentil (*Lens culinaris* L.)	BARI Masur-2	1.3-1.7	90-100

3.12.2. Land Preparation

The experimental field was well-prepared by 4 - 6 ploughing followed by laddering for leveling the soil. For rice cultivation, the cross ploughing was done by the cultivator before applyingirrigation water for puddling.

3.12.3.Application of Fertilizers

The fertilizer combinations of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP), Gypsum, Zinc Sulphate, Boric acid, cow dung, poultry manure and oilcake were applied in Sara and Gopalpur series and theirquantity are presented in Table 3.8 and Table 3.9. Fertilizers were applied by following the methods mentioned in Fertilizer Recommendation Guide-2012 of Bangladesh Agricultural Research Council (BARC, 2012) for jute, T.aman, mustard and lentil. The entire amount of cow dung, poultry manure and oilcake was applied before land preparation. One third (1/3) or half (1/2) of whole amount of Urea and total amount of MP, TSP, Gypsum, Zinc Sulphate and Boric acid were applied at the time of final land preparation. The remaining Urea was top dressedfollowed by irrigation in rest or two equal installments at certain days after sowing (DAS). The methods for fertilizer application were used as per recommendation for individual crop.

3.12.4. Seed Sowing

The tested crops were jute, T.aman, mustard and lentil. The sowing time for all the crops was followed as per recommendation of BJRI (2001) for jute, BRRI (2000) for T.aman rice, DAE (2015) for mustard and lentil.

Jute:

The jute seeds were broadcasted @ 8 kg/ha to the plot.

Transplanted aman (T.aman):

Twenty two days old seedlings were transplanted in the experimental field. Distances of 20 cm from row to row and 15 cm from plant to plant were maintained.

Mustard:

Mustard seeds at the rate of 8.0 kg ha^{-1} were sown at the first week of November. Sowingwas done after final ploughing and then by laddering the plots were leveled.

Lentil:

The seed rate of lentil was 40 kg/ha and wasbroadcastedto the individual plots (Islam *et al.*, 2015). The recommended plant population for lentil is 130 m^{-2}. Crop stands of this density provide good competition against weeds and result in higher yields compared to thinner stands. The seeds were sown in the experimental plots at the first week of November.

3.12.5. Weeding and Thinning

The crops were kept free from weeds by regular weeding and hoeing as per requirement of individual crop. Particular care was taken at the initial stage of growth to avoid disruption of crop growth by weeding.

3.12.6. Irrigation and Water Management

The transplanted aman rice fields in kharif-II season were kept flooded throughout the growing period excepting the time of cultural practices. Irrigation was given throughirrigation channels just after transplanting of the settlings for easy establishment. Also supplementary irrigation were done during the dry period depending on the crop growth as and when required.

3.12.7. Pest and Disease Management

Pest management and disease controls were done following the mechanical and chemical practices as recommended by the Bangladesh Rice Research Institute (BRRI) and Department of Agricultural Extension (DAE).

3.12.8. Harvesting

The crops were harvested after ripening or maturity. Plants were harvested in the morning and were brought in the threshing floor immediately.

3.12.9. Data Collection

Starting from planting/transplanting up to final harvesting the data on different parameters were taken.Data of jute, T.aman, mustard and lentil were recorded from onesquaremeter area from each plot and then converted into yield per hectare. All the crops were cut at the ground level. Threshing, cleaning, and drying of grain were done separately plot wise. The yields of each crop were recorded plot wise.

3.13. Plant Sampling Procedures

Plant and leaf samples were collected for each crop from the experimental field according to the techniques presented in Table 3.12. Randomly selected five crops from the middle of each unit plot were collected to make one composite sample.

Table 3.12. Collection of plant samples.

Crop	Parts	Sample collection techniques
Jute	Leaf	From defoliated and new leaves before harvesting.
	Stick	From whole stick with bark of the harvested plant.
Rice	Straw	As whole plant without root and grain at the time of harvest.
	Grain	250 g air dried rice grain
Mustard	Stover	As whole plant without root and grain at the time of harvest.
	Grain	100 g air dried grain
Lentil	Stover	As whole plant without root and grain at the time of harvest.
	Grain	100 g air dried grain

3.14. Soil Sampling Procedure

Before setting the experiments and after the harvest of each crop, soil samples were collected from each experimental plot by using spade for measuring nutritional status of soils. Soil samples were taken near the base of each plant at a depth of 0-15 cm using spade. A composite sample for each plot was prepared from an average of five sub-samples collected from each unit plot. The soil and plant samples were put into polythene bags for transporting to the laboratory.Surface and subsurface soil samples were also collected from sixteen different locations of Kashiani upazila and were put into polythene bags for transporting to the laboratory for analysis.

3.15. Preparation of Collected Samples

Prior to laboratory analysis, the collected soil samples were air-dried, ground and screened to pass through 2 mm sieve. The sieved samples were preserved in plastic containers and labeled properly.

Plant samples were gently washed with tap water followed by distilled water for removal of soil or dust and then oven dried at 70^{o}C for 48 hours for achieving constant weight of dry plant samples. The dried samples were ground and then were stored in air-tight containers for chemical analyses.

3.16.Methods for Analysis of Soil and Plant

Soil and plant samples collected from different plots were analyzed to determine chemical properties of the samples. The methods used for the determinations are presented in the following sections.

3.16.1. Methods for Physical Properties Analysis of Soil

3.16.1.1. Particle size analysis

The particle size analysis (PSA) of the soil was carried out by hydrometer method (Bouyoucos, 1927). The textural classes were determined by Marshall's triangular co-ordinates as derived by the United States Department of Agriculture (USDA, 1951).

3.16.1.2. Moisture content

The moisture content of air-dried sample was determined by drying known amount of sample in an oven at 105^{0}C for 48 hours until constant weight was obtained and the moisture percentage was calculated from the loss of the moisture from the samples.

3.16.1.3. Bulk density

Bulk density was determined by core method as described by Blake (1965). Undisturbed soil samples were collected using metal cores. The volume of the sample was measured and then the oven-dry weight of that sample was determined.

3.16.1.4. Particle density

Particle density of the soil was determined by pycnometer method as described by Blake (1965).

3.16.1.5. Total porosity of soil

Percentage porosity of soil was calculated from the values of bulk density (BD) and particle density (PD) (Brady and Weil, 2002) as:

% Porosity = (1- Bulk density/ Particle density) x 100

3.16.1.6. Hydraulic conductivity of soil

Saturated hydraulic conductivity of the soils was determined in the laboratory using undisturbed core samples by constant head method as described by Klute and Dirkson (1986).

3.16.2. Methods forAnalysis of Soil Chemical Properties

3.16.2.1. Soil pH

Soil pH was measured electrochemically by using a glass electrode pH meter (Jenway 3305). The soil-water ratio was 1 : 2.5 and time of shaking was 30 minutes as outlined by Jackson (1958).

3.16.2.2. Soil organic carbon

The total organic carbon of the samples was determined by wet oxidation method (Walkley and Black, 1934). Organic matter was calculated by multiplying the percent value of organic carbon by conventional van Bemmelen's factor of 1.724.

3.16.2.3. Cation exchange capacity (CEC)

The cation exchange capacity (CEC) of soil was determined by using ammonium acetate as described by Schollenberger and Simon (1945).

3.16.2.4. Total nitrogen (N)

For determination of total nitrogen, the sample was digested by Kjeldahl's method as described by Jackson (1958).

3.16.2.5. Available phosphorus (P)

Available soil phosphorus was extracted by following Olsen *et al.* (1954) method. Amount of phosphorus in the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962). The absorbance by color was determined by using Spectrophotometer (Jenway 6310) at 882 nm wavelength.

3.16.2.6. Available sulphur (S)

Available soil sulphur was extracted with 500 µg P ml^{-1} of phosphorus using $Ca(H_2P0_4)_2.2H_2O$ (Fox *et al.*, 1964). The extracted available sulphur was measured turbidimetrically (Hunt, 1980). The turbidity of the sample was determined by using Spectrophotometer (Jenway 6310) at 420 nm wavelength.

3.16.2.7. Ammonium acetate extractable cations

Ammonium acetate extractable calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) were extracted by 1N neutral ammonium acetate (Schollenberger and Simon, 1945). Calcium and magnesium contents of the extract were determined by Atomic Absorption Spectrophotometer (Varian AA240) and potassium and sodium contents were determined by using a Flame Photometer (Jenway PFT7).

3.16.2.8.DTPA extractable cations

Available Iron (Fe), Manganese (Mn), Zinc (Zn) and Copper (Cu) were extracted with diethylenetriaminepentaacetic acid (DTPA) (Lindsay and Norvell, 1978). The elements were determined by using an Atomic Absorption Spectrophotometer (Varian AA240).

3.16.2.9. Heavy metal determination

Soil samples were wet digested with nitric-perchloric acid as described by Piper (1966) for determination of lead (Pb), cadmium (Cd) and nickel (Ni). Total Pb, Cd and Ni in the digest were determined by Atomic Absorption Spectrophotometer (Varian AA240).

3.16.3. Methods for Plant Analysis

Plant samples collected from plots of different experiments were analyzed to determine the nutrient status in the tested crops. The techniques used for the determination of different nutrients are presented as follows.

3.16.3.1. Digestion of plant samples

Plant materials were wet digested with nitric-perchloric acid as described by Piper (1966) for determination of total Phosphorus (P), Sulphur (S), Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Iron (Fe), Manganese (Mn), Zinc (Zn) and Copper (Cu).

3.16.3.2. Total N

For determination of total nitrogen, the samples were digested by Kjeldahl's method as described by Jackson (1958).

3.16.3.3. Total P

Total P content of the digest was determined by vanadomolybdophosphoric yellow color method using Spectrophotometer (Jenway 6310) as described by Jackson (1958).

3.16.3.4.Total K and Na

Total potassium (K) and Sodium (Na) in the nitric-perchloric acid digest was measured by Flame Photometer (Jenway PFT7).

3.16.3.5. Total S

Total sulphur in the nitric-perchloric acid digest was measured turbidimetrically (Hunt, 1980). The absorbance was measured at 420 nm wavelength by Spectrophotometer (Jenway 6310).

3.16.3.6. Total Ca, Mg, Fe, Mn, Zn and Cu

Total contents of calcium, magnesium, iron, manganese, zinc and copper in the nitric-perchloric acid digest were determined by Atomic Absorption Spectrophotometer (Varian AA240).

3.17. Nutrient Uptake

The uptakes of nutrients were also calculated from the yield and the nutrient concentration of crops grain/stover/steam/leaves. Nutrient uptake by plants from soils was calculated by using the following formula:

Nutrient uptake, NU $= \frac{\% A \times Y}{100}$ kg ha^{-1}

Where,%A = Nutrient (N,P, K etc.) concentrations in grain/stover/steam/leaves

Y = Weight of grain/stover/steam/leaves (kg ha^{-1})

3.18. Apparent Nutrient Balance

The "partial" nutrient balance, including only major inputs (fertilizer and manures) and major outputs (nutrient removal by crops) were considered.

3.19. Statistical Analysis

The recorded data on different parameters and various characteristics of crops were subjected to statistical analysis. The analysis of variance for soil physical and chemical parameters, crops yield and yield contributing parameters and nutrients content and uptake related parameters was performed following ANOVA technique and the mean values were adjusted by Duncan's Multiple Range Test (DMRT) method. All data were analyzed in the computerusing SPSS Statistical 20, a software for statistical analyses. Computation and preparation of graphs were done by using Microsoft Excel 2007program. The difference between treatment means was compared by Least Significance Difference (LSD).

CHAPTER 4
RESULTS AND DISCUSSION

This chapter includes results on the available nutrient content of soils in two different series and yield of crops as influenced by management practices and cropping intensity. This study also includes nutrient concentrations in grain and straw/stover/stick in crops grown under Jute-T. aman- Mustard and Jute-T. aman -Lentil cropping system. The results are presented in tables and discussed accordingly.

4.1. Effect of Management Practices and Intensive Cropping on Physical and Chemical Properties of Soils

4.1.1. Effect on Physical Properties of Soils

Physical properties are the dominant factors influencing the uses of a soil which ranged from its suitability for a foundation of any infrastructure to its suitability for the production of different crop plants. The investigated physical properties of soil in this experiment were bulk density, particle density,total porosity, hydraulic conductivity and moisture content of soil.

4.1.1.1. Effect on Bulk Density

Among the physical parameters soil bulk density was greatly influenced due to combined application of chemical fertilizers (CF) and organic manures (Appendices4.1a and 4.1b). The application of chemical fertilizers individually or in combination with three different manuresproduced different results of soil bulk density. In soils of Sara and Gopalpur Series, bulk density showed significant difference among the treatments.Data indicated that chemicalfertilizers(fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers) alone played a role in increasing the bulk density, where all the contribution for lowering the bulk density was certainly due to the combined application of chemical fertilizers and organic manures.

In soils of Sara series,the highest 1.33 g cm^{-3}bulk density was observed with T_{10}treatment receiving only chemical fertilizers based on soil analysis, which decreased to 1.17g cm^{-3}due to the application of T_3(75% of farmers' practice + recommended S & B+5 t ha^{-1}cow dung)treatment in both years. Second (1.19 g cm^{-3}) and third (1.19 g cm^{-3}) lowest bulk densities were recorded with T_3treatment and treatment T_4 (75% of farmers' practice + recommended S & B + 3 t ha^{-1} poultry manure), respectively. Same trend of bulk density was observed in both yearswhen cow dung, poultry manure and oilcake applied in combination with 75% recommended fertilizer dose. It was also observed that bulk density of soilswith the chemical fertilizers +organic manures treated plots were lower than that of only chemical fertilizers(fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers) treated soils(Figure 4.1 and Appendix 4.1a).

In soils of Gopalpur series, highest bulk density (1.46 g cm^{-3})was also recorded with treatment T_{10},receiving only chemical fertilizers based on soil analysis and the value of bulk density was lowest (1.20 g cm^{-3})withT_3 treatment.The data showed that the bulk density with treatment T_4(1.23 g cm^{-3}),T_5 (1.25 g cm^{-3}), T_7 (1.22 g cm^{-3}), T_8 (1.24 g cm^{-3}) and T_9 (1.27 g cm^{-3}) receiving organic manure with chemical fertilizer were also lower than the bulk density withtreatment T_1 (1.42 g cm^{-3}), T_2 (1.44 g cm^{-3}) and T_{10} (1.46 g cm^{-3}), receiving only chemical fertilizer and control (1.43 g cm^{-3}). The contribution of organic manures for lowering the bulk density followed the order of cow dung (@ 5 t ha^{-1}) > poultry manure (@ 3 t ha^{-1}) >oilcake (@ 2 t ha^{-1}). The reason for the better performance of cow dung than other two manures might be its higher rates of application (Figure 4.1 and Appendix 4.1b).

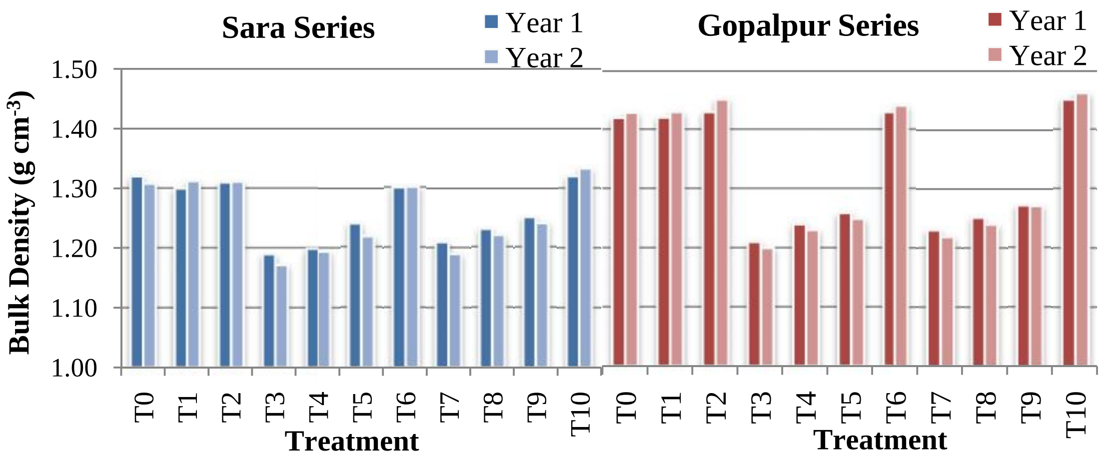

Figure 4.1. Bulk density (g cm^{-3}) of Sara and Gopalpur series as influenced by different treatments.

Data presented in Figure4.1 showed that the bulk density was higher in second year thanfirst year due to the application of chemical fertilizer only or application of no fertilizer, but bulk density decreased in second year than first year when organic manuresand chemical fertilizerswere applied combinedly. Both soil series possess the similar trend of increase or decrease in bulk density except T_1 treatment. Addition of organic manures to soil decreased the bulk density and this change might have the beneficial effects on agricultural aspects. It can be concluded that the quantity of organic manures rather than the source played an important role in reducing the bulk density of soil. In a 10 years' long study, Bellakki *et al.*(1998) found similar trend of bulk density having the values of 1.46 g cm^{-3} in control, and 1.36 g cm^{-3} and 1.31 g cm^{-3} in the treatment where cow dung and rice straw were applied, respectively. The trend of variation of bulk density inthis studygave similar indication that was observed by Shirani *et al.* (2002), Ghuman and Sur (2006), Hatik *et al.* (2006) and Khan *et al.*(2007).

4.1.1.2. Effect on Particle Density (PD)

The effects of applied chemical fertilizers alone or in combination with organic manures on particle density of soil in two years of experiment are shown in Appendices 4.1a and 4.1b. Soil particle density was non-significantly influenced by the addition of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake.Particle density also gives an indication about the level of organic matter.

In soils of Sara series, the value of soil particle density varied from 2.62 g cm^{-3} to 2.67 g cm^{-3}during two years of field experiments(Figure 4.2 and Appendix 4.1a). The lowest particle density (2.62 g cm^{-3}) was found in the soilstreated with T_5 (75% of farmers' practice + recommended S & B + 2 t ha^{-1}oilcake) and T_9treatment (75% of recommended fertilizers + 2 t ha^{-1} oilcake). The highest value of particle density (2.68 g cm^{-3}) was observed with T_1 (chemical fertilizers applied by farmers) treatment, which was similar to the T_2(chemical fertilizers applied by farmers + recommended S & B) and T_6 (recommended fertilizers) treatments.

In soils of Gopalpur series, particle density did not change appreciably but ranged from 2.63 g cm^{-3} to 2.68 g cm^{-3}in the second year (Figure 4.2 and Appendix 4.1b). The values of particle density found from different treatments were more or less same to the trend of Sara series. The highest particle density of 2.68 g cm^{-3} was found with T_1 treatment, which was statistically similar to the T_2, T_6 and T_{10} (soil analysis based treatment) treatments. The lowest value of particle density was noted with T_5, T_7(75% of recommended fertilizers + 3 t ha^{-1} poultry manure)and T_9treatments. The lowest particle density was observed in treatments receiving chemical fertilizers and organic manures, where the highest was found in treatment receiving only chemical fertilizers i.e. fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers or without fertilizer.

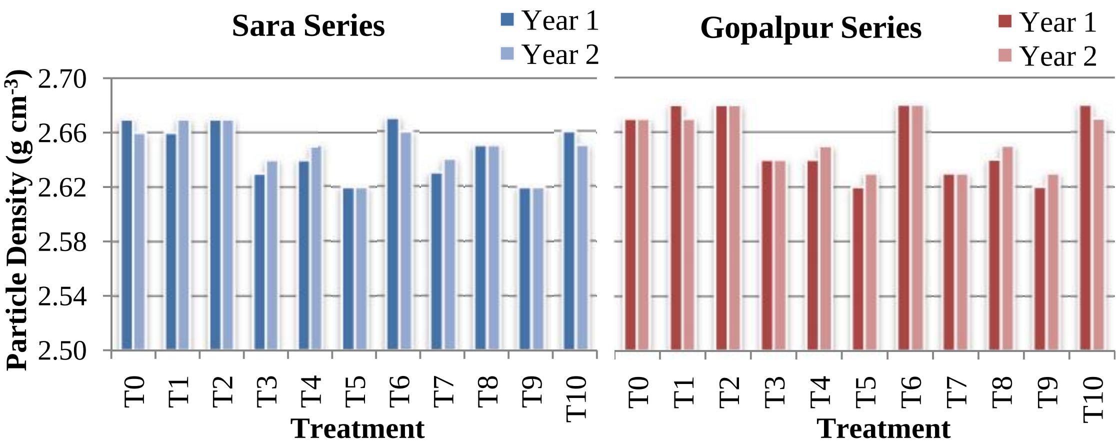

Figure 4.2. Particle density (g cm^{-3}) of Sara and Gopalpur series as influenced by different treatments.

Figure 4.2 shows that particle density was slightly higher in only chemical fertilizer treated soil than in soils of other plots treated combinedly with chemical fertilizer and organic manure. Particle density of soils was also higher in Gopalpur series than Sara series. Particle density decreased in organic manure treated soils in the second year compared to first year, but opposite trend was showed by the soils treated with chemical fertilizer only (Figure 4.2). Mathew and Nair (1997) obtained comparatively low value of particle density in soils treated with cattle manure that agreed with the results of this study.

4.1.1.3. Effect on Total Porosity

The effect of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake on the soil porosity of two years was statistically significant for Gopalpur series, but non-significant for Sara series (Appendices 4.1a and 4.1b).Integrated use of chemical fertilizer and organic manures provided highest values in all cases.

In soils of Sara series, the total porosity of soil under different treatments varied non-significantly from 50.34% to 54.73%in the first year and from 49.73% to 55.56% in the second year. The lowest porosity (50.34% and 49.73%) was noted with treatment T_{10} receivedchemical fertilizers based on soil analysis, which was significantly lower than all other treatments in both years. The highest soil porosity (54.73% and 55.56%) was recorded with T_3treatment receiving75% of farmers' practice + 75% of recommended S & B + 5 t ha^{-1} cow dung, which was higher than all other treatments during two years of experiments. The values of total soil porosity in chemical fertilizer and organic manures treated soils were comparatively higher than the values of total porosity in only chemical fertilizer treated soils. The results give an indication about the increased porosity due to application of chemical fertilizers and organic manures (Appendix 4.1a and Figure 4.3).

In soils of Gopalpur series, almost similar trend of result was observed to that of Sara series, where total porosity was highestin the second year than first year in soils treated combinedly with chemical fertilizers and organic manures. Soil porosity decreased significantly in the second year due to the application of chemical fertilizer alone. The highest soil porosity of 54.57% was recorded with T_3treatment receiving75% of farmers' practice + 75% of recommended S & B + cow dung and the lowest porosity of 45.29% was found with T_{10}treatment receivingsoil testbased fertilizers on during the two years of field experiments. The results of total porosity in soils treated combinedly with chemical fertilizer and organic manures were higher than the results in soils treated with only chemical fertilizer. The results give an indication about the increased porosity due to the application of organic manures (Appendix 4.1b and Figure 4.3).

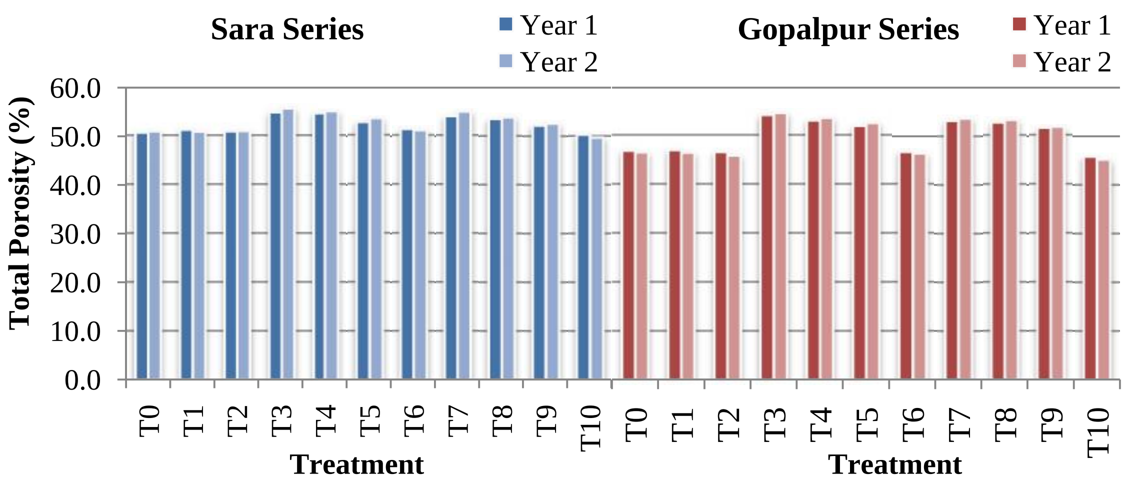

Figure 4.3. Total porosity (%) of soil of Sara and Gopalpur series as influenced by different treatments.

Figure 4.3 represents the total porosity of soils under ten different treatments for the period of two years. The figure clearly shows the highest values of soil porosity in organic manure based treatments and lowest values for only chemical fertilizer based treatments. Total soil porosity was comparatively higher in Sara series than the soils of Gopalpur series. The incorporation of organic manures improved soil physical properties that was evident from the values of porosity of soil. Similar observation was reported by Bellakki *et al.*(1998) who found porosity of 44% in the control plots; and 47.5% and 51.5% in the treatment with cow dung and paddy straw respectively. The findings of

Mathew and Nair (1997), Vennila and Muthuvel (1998), Haynes and Naidu (1998) and Selvi *et al.*(2005) also corroborated with the observation of this study.

4.1.1.4. Effect on Hydraulic Conductivity (Ks)

Hydraulic conductivity is an important soil property that involves in the behavior of soil water flow. The results on the hydraulic conductivity of water through the soil column are presented in the Appendices 4.1a and 4.1b. The hydraulic conductivities in both soils were significantly influenced due to the application of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake.

In Sara series, the saturated hydraulic conductivity varied from 12.51 mm h^{-1} to 15.05 mm h^{-1}in the first year and from 12.22 mm h^{-1} to 15.19 mm h^{-1}in the second year. The hydraulic conductivity of soil increased from14.56 mm h^{-1} to 14.62 mm h^{-1}, from 13.88 mm h^{-1} to 13.94 mm h^{-1} and from 13.55 mm h^{-1} to 13.68 mm h^{-1}in the second year due to the application of 75% of recommended fertilizers + cow dung (T_7), 75% of recommended fertilizers + poultry manure (T_8) and 75% of recommended fertilizers + oilcake (T_9) treatments, respectively. In case of only chemical fertilizer application, thevalues of hydraulic conductivity of treatment T_1,T_2, T_6 and T_{10}reduced from 12.85 mm $h^{-1}$to 12.42 mm h^{-1}, from 13.21 mm $h^{-1}$to 12.75 mm h^{-1}, from 12.53 mm $h^{-1}$to 12.23 mm $h^{-1}$and from 12.51 mm $h^{-1}$to 12.22 mm h^{-1}respectively. The highest bulk density was recorded with T_7 treatment which was statistically similar to T_3, T_4, T_5, T_8 and T_9 treatments, but dissimilar to the rest of the treatments. The trends of hydraulic conductivity with only chemical fertilizer treated soils were opposite to the hydraulic conductivity with organic manure (cow dung, poultry manure and oilcake) treated soils (Appendix 4.1a and Figure 4.4).

In Gopalpur series, the statistically significant saturated hydraulic conductivity for the first year and second year ranged between 11.22 and 14.87 mm h^{-1}. The hydraulic conductivity of soils treated with75% of recommended fertilizers + cow dung was higher in both soils. The values of hydraulic conductivity increased from the first year to second year in soils with treatment T_3 (12.53 mm $h^{-1}$to 13.21 mm h^{-1}), T_4 (13.88 mm $h^{-1}$to 14.13 mm h^{-1}), T_5 (14.56 mm $h^{-1}$to 14.82 mm h^{-1}), T_7 (14.70 mm h^{-1} to 14.87 mm h^{-1}), T_8 (13.55 mm $h^{-1}$to 13.78 mm h^{-1}) and T_9 (13.21 mm h^{-1} to 13.45 mm h^{-1}), received both chemical fertilizers and organic manures. The highest bulk density was recorded with T_7 treatment which was statistically identical to T_3, T_4, T_8 and T_9 treatments, but superior to the rest of the treatments. The results of hydraulic conductivity were higher in organic manurestreated plots and lower withonly chemical fertilizersi.e. farmers' practice or recommended fertilizers or soil test based treatment. The trends of hydraulic conductivity were found similarto that of Sara series (Appendix 4.1b and Figure 4.4).

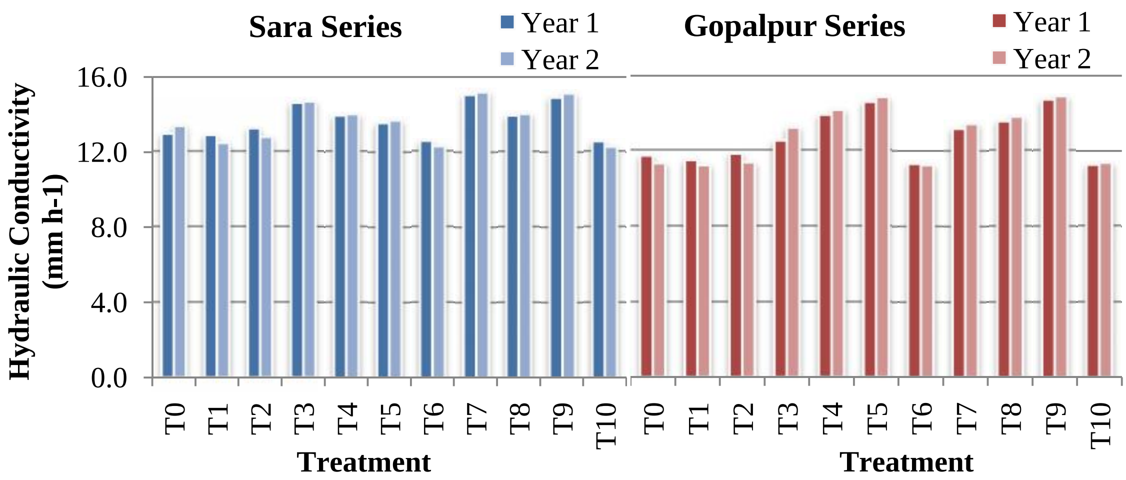

Figure 4.4. Saturated hydraulic conductivity (mm h^{-1}) of soil of Sara and Gopalpur series as influenced by different treatments.

The high conductivity of water in the organic manure treated soils indicated comparatively lower bulk density and higher porosity that permits the downward movement of water. Figure4.4 shows that the hydraulic conductivity values in cow dung, poultry manure and oilcake treated soils were different and follows two different ordersCF + CD> CF + PM> CF + OC> CF in Sara series and CF + OC> CF + PM> CF + CD> CF in Gopalpur series. The results of the present study agreed with the observation of Haynes and Naidu (1998), who found that the addition of organic manures increased the hydraulic conductivityof soil. The findings of Bellakki *et al.*(1998), Vennila and Muthuvel (1998) and Khan *et al.*(2007) were also found similar to the trend of hydraulic conductivity.

4.1.1.5. Effect on Soil Moisture Content

The effect of soil management practices through application of chemical fertilizers alone or in combination with organic manures on soil moisture content is given in Appendices 4.1a and 4.1b. The effectson moisture content were statistically significant in both Sara and Gopalpur series except 1st year in Sara series.

In Sara series, soil moisture contents ranged from 17.09 to 19.91% in the first year and from 16.85 to 20.84% in the second year due to application of different treatments. The moisture content decreased in the second yearcompared to first year with treatment T_1, T_2, T_6 and T_{10}which received only chemical fertilizers. Whereas the moisture content of soils increased in the second year compared to first year with treatment T_3, T_4, T_5, T_7, T_8 and T_9 where different organic manures applied with chemical fertilizers (Appendix 4.1a and Figure 4.5).

In Gopalpur series, the effect of different treatment combinationson moisture contents of soils varied between 17.09% and 19.91% in the first year and between 16.85% and 20.84% in the second year. Two different trends were observed for the application of different treatments and intensive cropping. The moisture content of soils with treatment T_3, T_4, T_5, T_7, $T_8$and T_9 plots in the second year compared to first year increased due to increasing organic matter content for regular organic manures application. The moisture content of the soils reduced in the second yearcompared to first year with treatment T_1, T_2, T_6 and T_{10} which received chemical fertilizersonly and control (Appendix 4.1b and Figure 4.5).

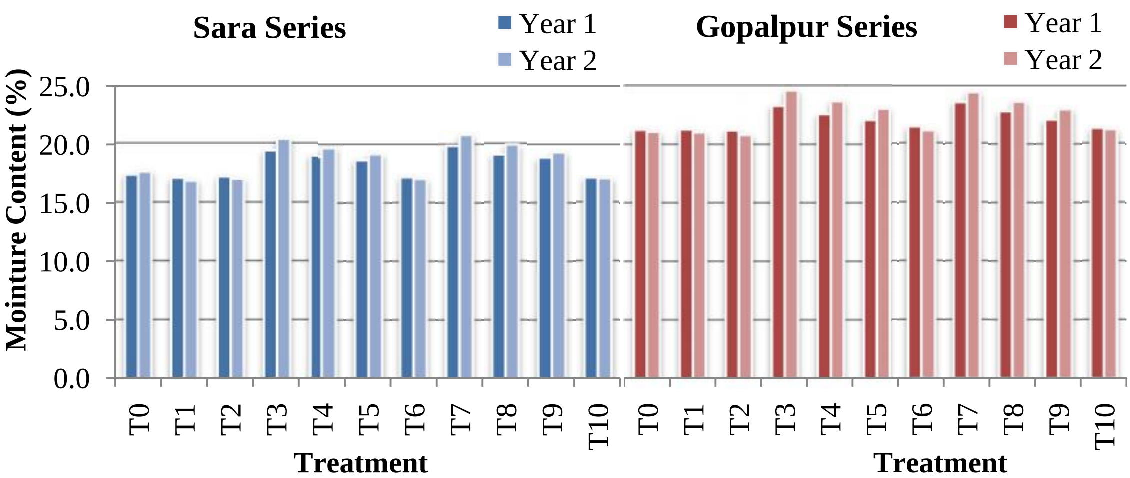

Figure 4.5. Soil moisture content of Sara and Gopalpur series as influenced by different treatments.

Figure 4.5 shows the different treatment based moisture content of soils. In the figure, combined application of chemical fertilizers and organic manures represented the highest moisture contentbars where application offertilizers applied by farmers or recommended fertilizers or soil test based treatment represented the lowest moisture content bars. In both series, the moisture content of soils was different in different organic manure treated soils, the order was CD>PM>OC> CON >CF. The highest bar of percent moisture content was found in the second year in case of organic manures application when compared against the value of first year. Same trend was observed both in Sara and

Gopalpur series. The quantity of organic manure application to the experimental plots was an important factor for enhancing the moisture content of soil. The observation corroborated with the findings of Gagnon *et al.*(1998) who found that soil water content increased with increasing rates of composts application. The organic manures significantly improved the water holding capacity of soil that was found from the study also agreed withLandon (1991)and Ouattara *et al.* (2006).

4.1.2. Effect on Chemical Properties of Soils

4.1.2.1.Effect on Soil Organic Matter (SOM) Content

The soil organic matter content (SOM) of the experimental plots under different treatments as observed in two years of experiment are presented in Appendix 4.2. The initial and final data of SOM revealed that there was a significant change in SOM due to the application of chemical fertilizer alone or in combination with organic manures after two years of crop growth.

In Sara series, all treatments showed decline insoil organic matter(SOM) content in two years of field experiments. In the first year, the highest SOM content of 1.50% was recorded with T_4(75% of farmers' practice + 75% recommended S & B + poultry manure) treatment which was statistically similar to T_2, T_3, T_5, T_7, T_8 and T_9 treatments and the lowest SOM content of 1.21% was found with treatment T_0 (control).In the second year, the combined application of chemical fertilizers and organic manures provided higher level of soil organic matter (1.34-1.50%) and the chemical fertilizers amended plots showed the lower level of SOM (1.23-1.35%).The decline in SOM in soils treated with chemical fertilizer only was 0.24 - 1.36% which showed lowest decline. The highest declined range of SOM was 1.00 - 4.14% which was found in soils treated combinedly with chemical fertilizer and organic manures(Appendix 4.2 and Figure 4.6).

In Gopalpur series, the effect of chemical fertilizer alone or in combination with organic manures on soil organic matter (SOM) content was significant in the first year(Appendix 4.2). The value of SOM content ranged between 1.38% and 1.81% in both years. The SOM content was lower (1.38 – 1.45%) in soils treated with chemical fertilizers alone and was higher (1.58 – 1.81%) in soils treated combinedly with chemical fertilizer and organic manures (cow dung, poultry manure and oilcake). The results gave a clear indication about the decline in SOM content from first year to second year. The least decline of 1.27% in SOM content was recorded with treatment T_0(control) whilst the highest decline of 8.25% was found with treatment T_3 (75% of farmers' practice + 75% of recommended S & B + 5 t ha^{-1}cow dung) in both years. The highest soil organic matter content was observed in cow dung treated plots (Appendix 4.2 and Figure 4.6).

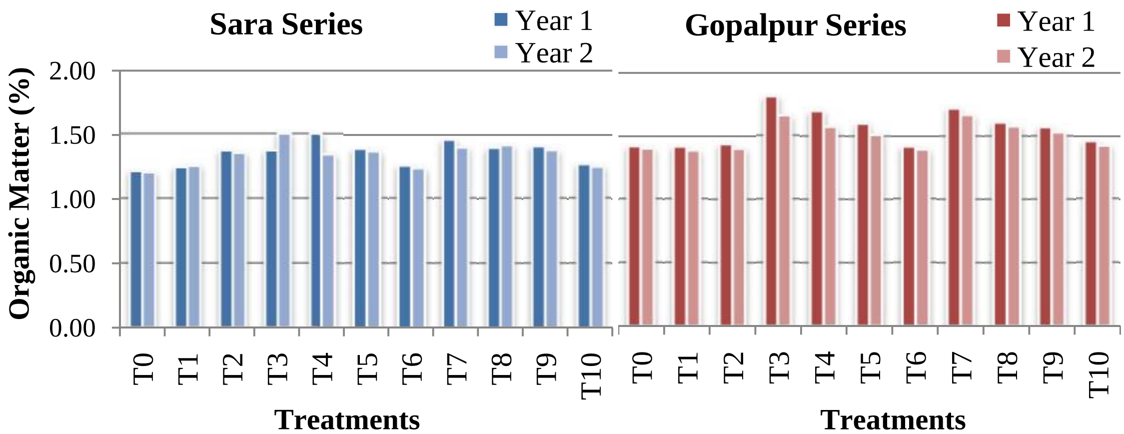

Figure 4.6. Soil organic matter content of Sara and Gopalpur series as influenced by different treatments.

Figure 4.6 shows that the organic matter content of soils declined from the first year to second year. The results indicated that SOM content was higher with chemical fertilizers + organic manures treated plots than that of only chemical fertilizers (fertilizers applied by farmers or recommended fertilizers or soil test based treatment) treated plots or the control. In both soil series, soil organic matter contents were higher in soils treated combinedly with chemical fertilizers and organic manures, and the order was CD+CF >PM+CF >OC+CF > CON >CF. In general, recorded soil organic matter content in both years of study ranged from 1.20-1.81%, which was lowerthan soil organic matter content suggested byRanamukhaarachchi *et al.*(2005). A decline in organic matter is considered to create an array of negative effects on crop productivity (Katyal *et al.*, 2001). The combined application of chemical fertilizers and organic manures over two years increased SOM content over the application of chemical fertilizer alone that was found by Mann *et al.*(2006).Similar results were also noted by Islam (1990), Singh *et al.* (2006) and Srinivasarao *et al.* (2011) who stated that the combined application of chemical fertilizers and organic manures increased the organic matter content of soils from the initial status.

4.1.2.2.Effect on Soil pH and Acidity

The application of chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake non-significantly influenced thesoil pHfor both Sara and Gopalpur series (Appendix 4.2).

In Sara series, pH values ranged from 7.73 to 7.88 and 7.73 to 7.93 in the first and second years, respectively. Data indicated that the combined use of chemical fertilizer and organic manures reduced soil pH from its initial pH (7.71) by 0.78%, 0.39%, 0.13%, 0.65%, 0.52% and 0.52% withtreatment T_3, T_4, T_5, T_7, T_8 and T_9, respectively. But the fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers increased the pH from the initial value by 0.39%, 0.52%, 0.65% and 0.52% with treatment T_1, T_2, T_6 and T_{10}, respectively (Appendix 4.2 and Figure 4.7).

In Gopalpur series, pH of soils varied from 7.48with T_3 treatment to 7.57with T_2 treatment and T_{10} treatment in the first year and varied from 7.49with T_3 treatment to 7.61 with T_{10} treatment in the second year. The results of pH under different treatments indicated that the pH declined from the initial pH (7.46) in soils treated combinedly with chemical fertilizer and organic manures i.e. T_3, T_4, T_5, T_7, T_8 and T_9 treatments, and pH increased in only chemical fertilizer treated plots i.e. T_1, T_2, T_6 and T_{10} treatments in both years. The result of pH with T_0 treatment showed decline trend. The lowest rate of decline in soil pH was 0.13%in soils treated with no fertilizer and the highest rate of pH decline was 0.40% in soils treated combinedly with chemical fertilizer and organic manures. The rate of increase in soil pH ranged between 0.13% and 0.40% during two years study period (Appendix 4.2 and Figure 4.7).

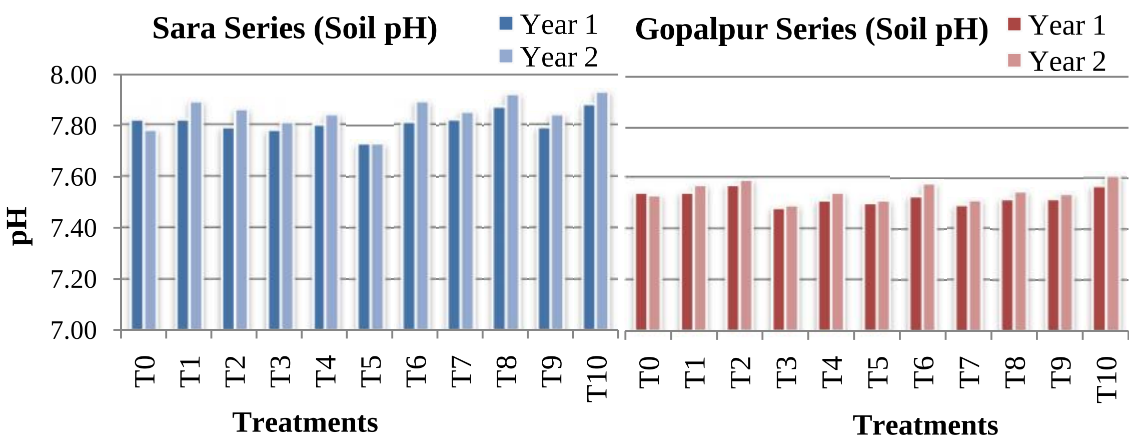

Figure 4.7. Soil pH of Sara and Gopalpur series as influenced by different treatments.

Figure4.7 shows the variation of pH values of two different soil series under the influence of different treatments in two years. It was found from the figure that pH of soils treated with chemical fertilizers alone increased in both soil series, but pH in soils treated combinedly with chemical fertilizer and organic manures decreased in the second yearcompared to the initial soil pH. Mian and Eaqub (1980) also found similar result where soil pH value slightly decreased due to the application of farmyard manure and green manure. More (1994) concluded from 3-years study that application of 25 t ha^{-1} FYM plus 20 t ha^{-1} pressmud decreased soil pH. Whalen *et al.*(2000) reported that cattle manure amendments increased soil pH from 4.8 to 6.0 and 5.5 to 6.3. The discussion revealed that organic manures tend to shift high pH to low pH that is closer to neutral.

4.1.2.3. Effect on CEC of Soils

The application of chemical fertilizers along with or without cow dung, poultry manure and oilcake significantly influenced the cation exchange capacity (CEC) of soil and the values are presented in Appendix 4.2.

In Sara series, the highest (17.71 cmol kg^{-1} soil) CEC was recorded with T_7 treatment which was statistically identical to T_3, T_4, T_5, T_8 and T_9 treatments, but dissimilar to the rest of the treatments in both years. TheCECof soils increased in the second year compared to the initial and/or the values of first year with T_3, T_4, T_5, T_7, T_8 and T_9 treatments which were treated with both chemical fertilizer and organic manures. In only chemical fertilizer treated plots the increase of CEC ranged from0.68-1.16%, which increased to 11.99-20.64% in combined application of chemical fertilizer and cow dung,7.22-12.40% in chemical fertilizer and poultry manure, and 9.20-15.26% in chemical fertilizer and oilcake treated plots (Appendix 4.2 and Figure 4.8).

In Gopalpur series, the highest (28.13 cmol kg^{-1} soil) CEC was recorded with T_7 treatment which was statistically identical to T_3, T_4, T_5, T_8 and T_9 treatments, but superior to the rest of the treatments in both years. theCEC of soil with T_1, T_2, T_6 and T_{10} treated plotsdecreased after two years of cropping from the initial value of 14.68cmol kg^{-1}soil, where only chemical fertilizers applied as treatments. In case of combined application of chemical fertilizer and organic manures, the results showed opposite trend. The CEC of soils increased with T_3, T_4, T_5, T_7, T_8 and T_9 treatments over the initial CEC value, where soils were treated with both chemical fertilizer and organic manures. The CEC of soils treated with only chemical fertilizer reduced from 0.57% to 1.23%, and CEC of soils increased from 5.24% to 15.05% that was treated with both chemical fertilizer and organic manure (Appendix 4.2 and Figure 4.8).

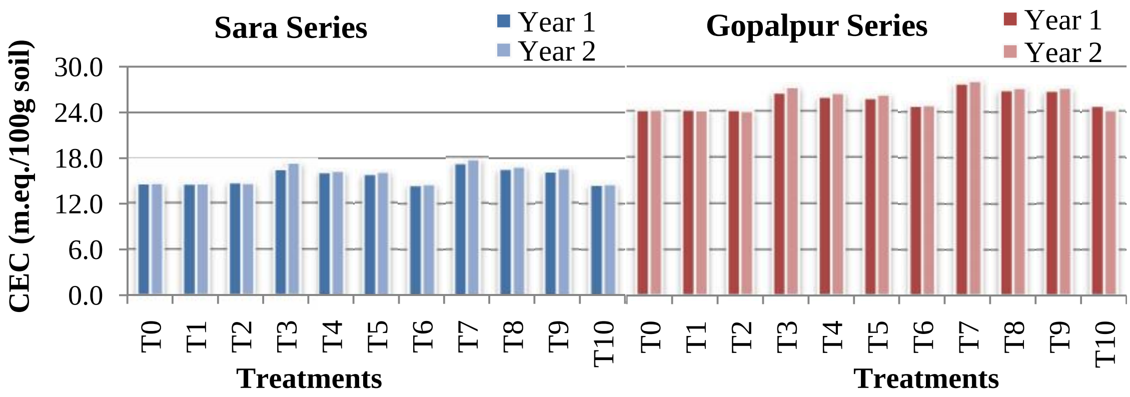

Figure 4.8. Cation exchange capacity (CEC) of soils of Sara and Gopalpur series as influenced by different treatment.

Figure 4.8 represents the CEC of the soils treated with different treatments for a period of two years in two different soils. In the figure, the higher values of CEC were found withorganic manures treated soils where lower CEC values were obtained with soils treated with only fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers. The above discussion indicated that the organic manures had positive impact on improving the cation exchange capacity of soil. Swarup (1979) showed a significant increase in CEC of soil with the application of farmyard manure. This finding was also supported by Bellakki *et al.*(1998)from a field experiment. The results of the present study also agreed well with the results found by Patiram and Singh (1993) who observed that the CEC of soil was increased by the application of manure.

4.1.2.4. Effect on C to N Ratio of Soils

The Carbon to Nitrogen (C/N) ratio of soil was non-significantly influenced due to the application of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake in two years of experiments(Appendix 4.2).

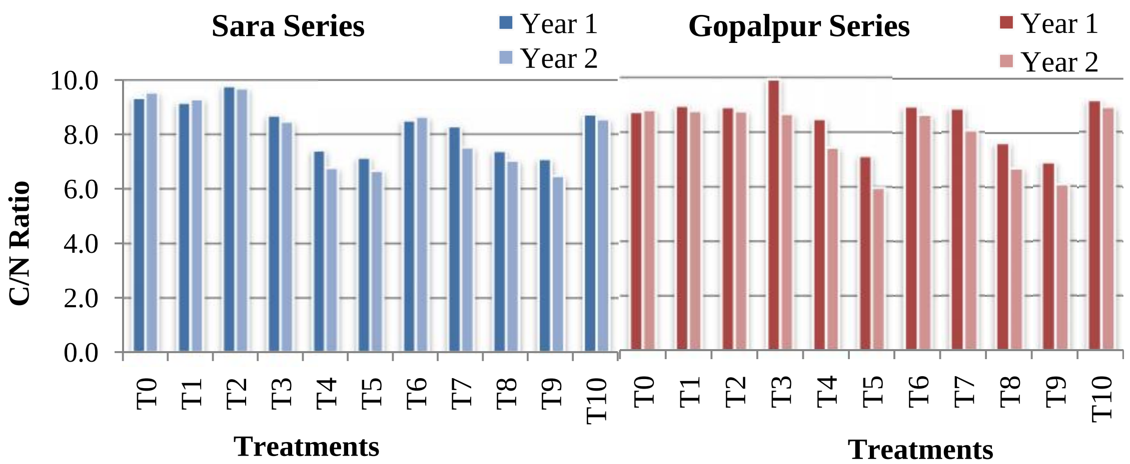

Figure 4.9. Carbon to Nitrogen (C/N) ratio of soils of Sara and Gopalpur series as influenced by different treatments.

Figure 4.9 shows that the C/N ratio of soils of Sara series increased in the second year than the first year, whereas in Gopalpur series, the ratio were reduced in the second year compared to first year. The results of C/N ratio of soils treated with chemical fertilizer and organic manures werebelow of 10. According to Brady and Weil (2002), the C/N ratio represented the passive fraction of soil organic matter that was in steady state.

4.1.2.5. Effect on Nutritional Status of Soils

4.1.2.5.1. Total Nitrogen (TN) Content in Soils

Appendices 4.3a and 4.3b show the total nitrogen content of post harvest soils that was significantly increased from the initial TN valuedue to application of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake for Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns during two years of experiments. In Sara series, the total nitrogen content of all the treated post harvest soils varied from 0.078% with T_1 treatment (chemical fertilizers applied by farmers) to 0.123%with T_9 treatment (75% of recommended fertilizers + 2 t ha^{-1}oilcake) in both years of experiments (Figure 4.10 and Appendix 4.3a).The highest value was recorded with T_9 treatment which was statistically identical to T_4, T_5 and T_9 treatments but dissimilar to the rest of the treatments in the second year. In Gopalpur series, the highest total nitrogen content of 0.148% was recorded with T_9 treatment which was statistically similar to T_4, T_5, T_7 and T_8 treatments in the second year. The lowest total nitrogen content of 0.092% was found with T_0 and T_1 treatments after two yearsfield experiments underJute - T. aman - Lentil cropping pattern(Figure 4.10 and Appendix4.3b). It gave an indication about the slow release of nitrogen and decreased loss from the soils.

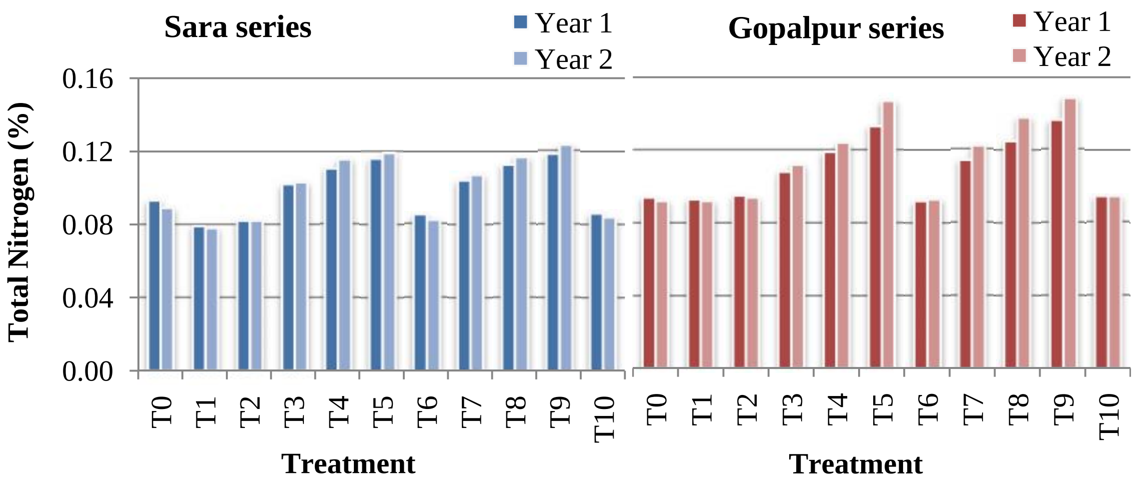

Figure 4.10. Total nitrogen of soils of Sara and Gopalpur series as influenced bydifferent treatments.

The results showed that the total nitrogen content was higher with the 75% of recommended fertilizers + oilcake treatment, which was followed by chemical fertilizers + poultry manure and chemical fertilizers + cow dung, compared to only chemical fertilizers treatments, composed of farmers' practice of fertilizers application or recommended fertilizers dose(s) or soil test based fertilizers in two years cropping (Figure4.10). The results of this study were similar to the findings of Shaktawat and Shekhawat (2010) and reported that the application of farmyard manure significantly increased the available nitrogen content in soil compared with the control.Ayoola and Makinde (2009) also reported that poultry manure increased soil N content by 41.7%, while cow dung increased the N content by 25%. Mann *et al.* (2006) found that the application of farmyard manure with optimum inorganic fertilizers increased the available N content of the soil significantly.

4.1.2.5.2. Available Phosphorus (P) Content in Soils

The results of available phosphorus content in soils treated with chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping systemsarepresented in Appendices 4.3a and 4.3b. Significant changes in soil available P were observed in post harvest soils with different fertilizer treatments and intensive cropping in both Sara and Gopalpur series. The available phosphorus contents were varied from 9.36 to 16.75 µg g^{-1}in Sara series and from 10.14 to 18.95 µg g^{-1} in Gopalpur series during two years of experiments (Figure 4.11 and Appendices 4.3a and 4.3b). The highest available P was recorded with T_4 treatment which was statistically identical to T_3, T_5, T_8 and T_9 treatments, but dissimilar to the rest of the treatments in both soil series. The available phosphorus content of soils was increased in all the treatments from the initial valuesin both the soils.

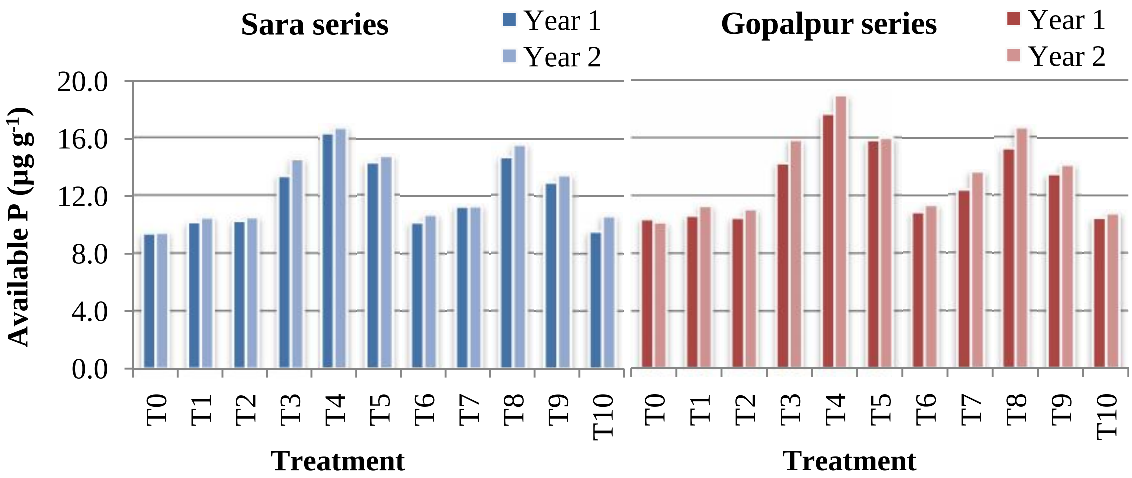

Figure 4.11. Available P in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.11 showsthat the highest valueof available P content was recorded with75% of farmers' practice + 75% of recommended S & B + poultry manure treatment in both Sara and Gopalpur series during the two years of study. Poultry manure can, therefore, be a good source of phosphorus for the studied soils. The higher level of available P in soils indicated that the combined applications of chemical fertilizers and organic manures such as cow dung, poultry manure and oilcake was comparatively better than only chemical fertilizers i.e. farmers' practice or recommended dose or soil test based treatment application.Bowman and Halvorson (1997) and Mckenzie *et al.*(1992) reported the effects of cropping system and fertilizer management on P availability and found that without fertilizer application, continuous cropping resulted in the greatest reduction of almost all soil organic and inorganic P pools. Gopinath and Mina (2011) reported that the application of farmyard manure 10 t ha^{-1} + recommended NPK, recorded significantly higher available P than plots under control.Mathew and Nair (1997) reported that cattle manure applied alone or in combination with chemical fertilizer of NPK increased the available P content in rice soils.

4.1.2.5.3. Available Sulphur (S) Content in Soils

The available S content was significantly influenced by the application of chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake (Appendices 4.3a and 4.3b). In Sara series, the highest (35.89µg g^{-1}) available S content was found with T_5 (farmers' chemical fertilizers + oilcake) treatment which was statistically similar to T_4 and T_9 treatments but dissimilar to the rest of the treatments and the lowest (14.37 µg g^{-1}) available S contents were recorded withT_0 (control) treatments in two years of experiments under Jute - T. aman - Mustard cropping pattern (Figure 4.12 and Appendix 4.3a). In Gopalpur series, the highest available S content of 41.70 µg $g^{-1}$was recorded with T_9(recommended chemical fertilizers + oilcake)treatment which was statistically identical to T_5 and T_8 treatments but dissimilar to the rest of the treatmentsin second year and the lowest value of 14.29 µg g^{-1} was obtained with T_0 (control) treatment (Figure 4.12 and Appendix 4.3b).The available S contents in soils with all treatments were higher than that of the initial available S values (14.18 µg g^{-1} in Sara and 17.47 µg g^{-1} in Gopalpur Series) under the two cropping patterns except the control.

Figure 4.12 shows the highest available S content with chemical fertilizers + oilcake which were followed by the chemical fertilizers + poultry manure and chemical fertilizers + cow dung treatments. The S contents were lower with the application of chemical fertilizer alone (farmers' practice or recommended fertilizers or soil test based) in two cropping patterns. The results gave a clear indication that cow dung, poultry manure and oilcake

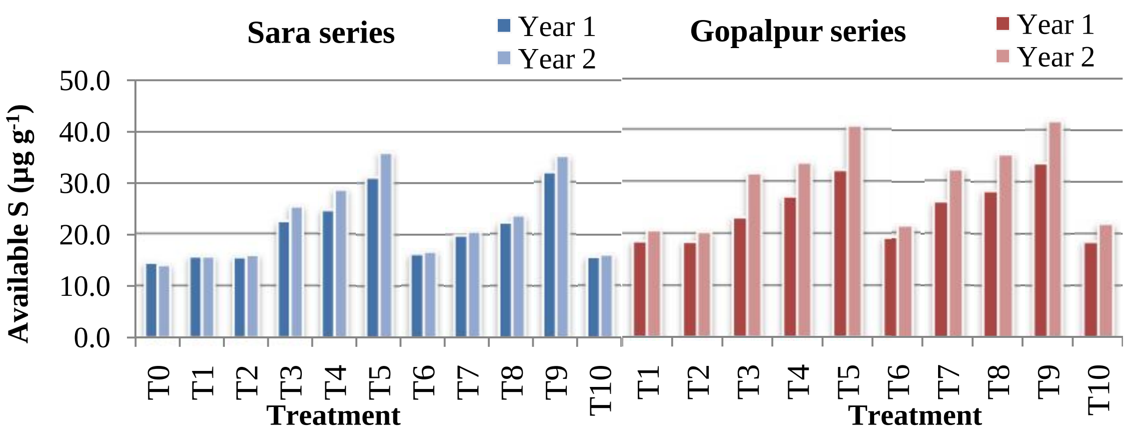

Figure 4.12. Available S in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

had significant effects on the available S contents in soils. The results observed in this experiment were supported by the findings of Rashid (2009). Sanchez (1976) reported that organic manure supplied most of the Sulphur to plants.

4.1.2.5.4. Available Boron (B) Content in Soils

Appendices 4.3a and 4.3b showthe available boron (B) content in soils that was non-significantly influenced due to the application of chemical fertilizer alone or in combination with organic manures under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns in two years of study. The available B content varied from 0.796 to 0.988 µg g^{-1}in Sara series and from 1.110 to 1.701 µg g^{-1} in Gopalpur series due to application of different treatments in two years of experiments (Figure 4.13 and Appendices 4.3a and 4.3b). The available B contents were increased with all the treatments compared to the initial available B values (0.816 µg g^{-1} in Sara and 1.182 µg g^{-1} in Gopalpur series) except the control.

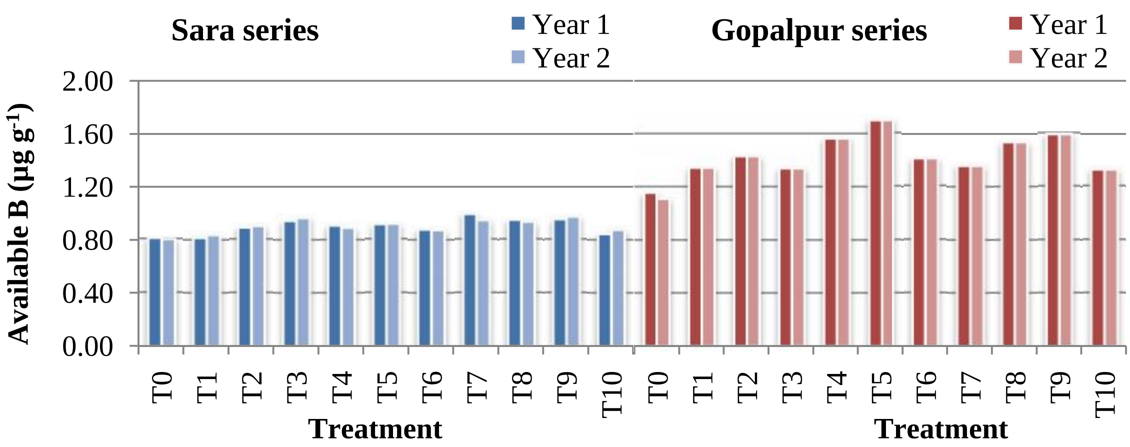

Figure 4.13. Available B content in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.13 shows the bars of available B content in soils due to application of different treatments in two years period for two series. The behavior of soils on the availability of B due to the application of treatment doses in two different soils wasdifferent. The results indicated that the response of cow dung + chemical fertilizers was better in Sara series, whereas the response of oilcake + chemical fertilizers was better which was followed by poultry manure + chemical fertilizersin Gopalpur series. It can be concluded from the above discussion that the organic manures had little influence on B availability under Jute - T. aman - Mustard and Jute - T. aman – Lentil cropping patterns.

4.1.2.5.5. Ammonium Acetate ExtractablePotassium (K) Content in Soils

The ammonium acetate extractable potassium (K) content in soils changed significantly due to application of different fertilizer treatments during two years of cropping with Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns in Sara and Gopalpur series, respectively. The ammonium acetate extractable K varied significantly from 0.150 to 0.227 cmol kg^{-1}soil in Sara series and from 0.231 to 0.387 cmol kg^{-1}soil in Gopalpur series (Figure 4.14 and Appendices 4.4a and 4.4b).The highest value was observed with T_3(75% of farmers' practice + 75% of recommended S & B + cow dung) treatmentwhich was statistically similar to T_4, T_5, T_7 and T_9 treatments but dissimilar to the rest of the treatments in both soil series and the lowest value was observed with the control. The application of different treatments increased the ammonium acetate extractable K contents in both soils from the initial ammonium acetate extractable K values (0.153 cmol kg^{-1}soil in Sara and 0.235 cmol kg^{-1}soil in Gopalpur series) in two years of experiments with Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns except the control.

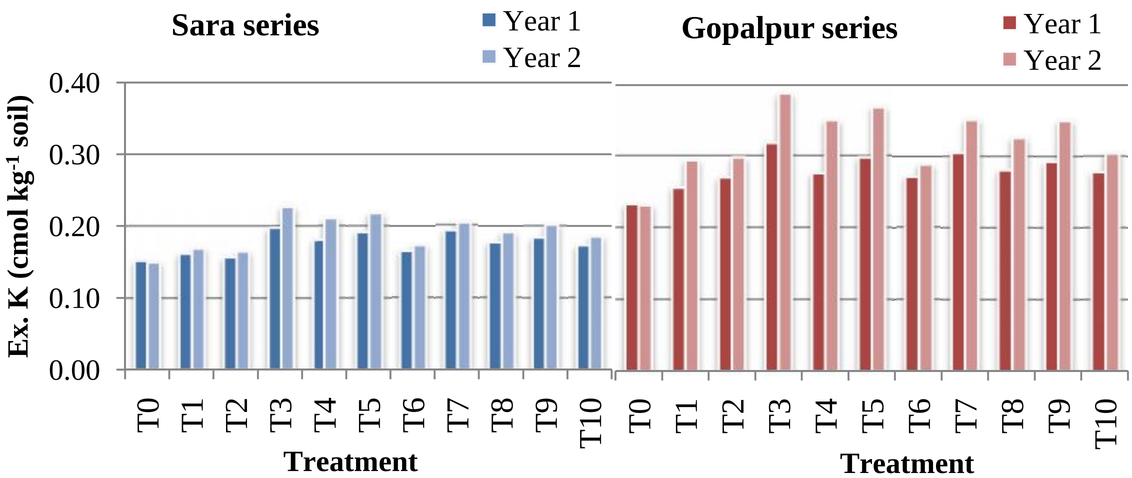

Figure 4.14. Ammonium acetate extractable K content in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.14 shows that the ammonium acetate extractable K contents in soils under two different cropping patternswere increased in the second year compared to first year. The use of chemical fertilizers +cow dung resulted higher ammonium acetate extractable K compared to the other treatments. Among the organic manures, performance of cow dung was better than that of poultry manure and oilcake under two different cropping patterns. The results of ammonium acetate extractable K found in this study were agreed withCassman (1995), Mian *et al.* (1983) and Shaktawat and Shekhawat(2010).Mann *et al.* (2006) and Mehla *et al.* (2008) also reported that the available K content also improved and the maximum K content was noticed where organic manure was added with inorganic fertilizers.

4.1.2.5.6. Ammonium Acetate ExtractableSodium (Na) Content in Soils

Appendices 4.4a and 4.4b show the ammonium acetate extractable sodium (Na) contentof post harvest soils that was non-significantly influenced due to the application of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake in Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns during two year periods. The ammonium acetate extractable Na content in soils treated with organic manures was increased slightlycompared tothe chemical fertilizer treated soils.

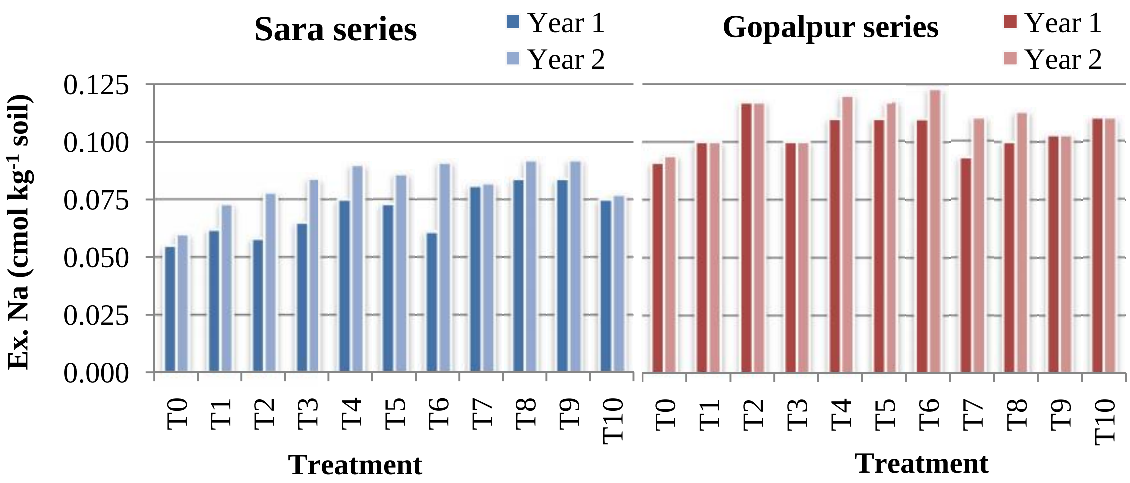

Figure 4.15. Ammonium acetate extractable Na content in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.15 shows that the ammonium acetate extractable Na content was increased in all soils after second year in both series and no definite trend was found due to the application of different treatments. This might be due to the addition of sodium from the source organic manures and irrigation water which were added to the soil. Lee *et al.* (2004) also reported that sodium content in soils was increased due to the application of compost.

4.1.2.5.7. Ammonium Acetate ExtractableCalcium (Ca) Content in Soils

Appendices 4.4a and 4.4b show the non-significant influence of chemical fertilizer alone or in combination with organic manures on the ammonium acetate extractable calcium (Ca) content of the soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns during two years study period. The ammonium acetate extractable Ca content was increased in soilsof both series under different treatmentscompared to the initial value of ammonium acetate extractable Ca content of the two soils.

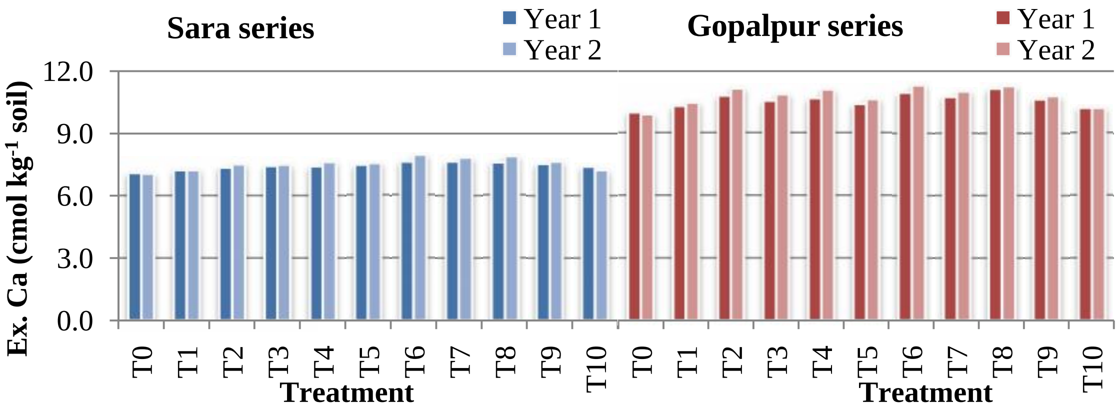

Figure 4.16. Ammonium acetate extractable Ca content in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.16 shows thatammonium acetate extractable Ca contentwas increased in the second yearcompared to first year. The heights of the bars resulted from each treatment in Gopalpur series were more or less similar but lower values were obtained in Sara series. IRRI (1975) reported that incorporation of organic matter returned Ca to the soil. Swarup (1991) found the improvement of Ca in soil due to the long term application of green manure, which was similar to the result of this study.

4.1.2.5.8. Ammonium Acetate ExtractableMagnesium (Mg) Content in Soils

The effects of chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake on the ammonium acetate extractable magnesium (Mg) content in soils are presented in Appendices 4.4a and 4.4b.The ammonium acetate extractable Mg content in soils was significantly influenced due to the application of fertilizer and manures in two years' of experiment with Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns. The highest Mg content was found with T_9 treatment which was statistically similar to T_3 and T_7 treatments in Sara series but dissimilar to the rest of the treatments at the end of two years period. In Gopalpur series, the highest Mg content was observed with T_7 treatment which was statistically similar to all other treatments except T_0, T_4 and T_{10} treatments at the end of two years period.

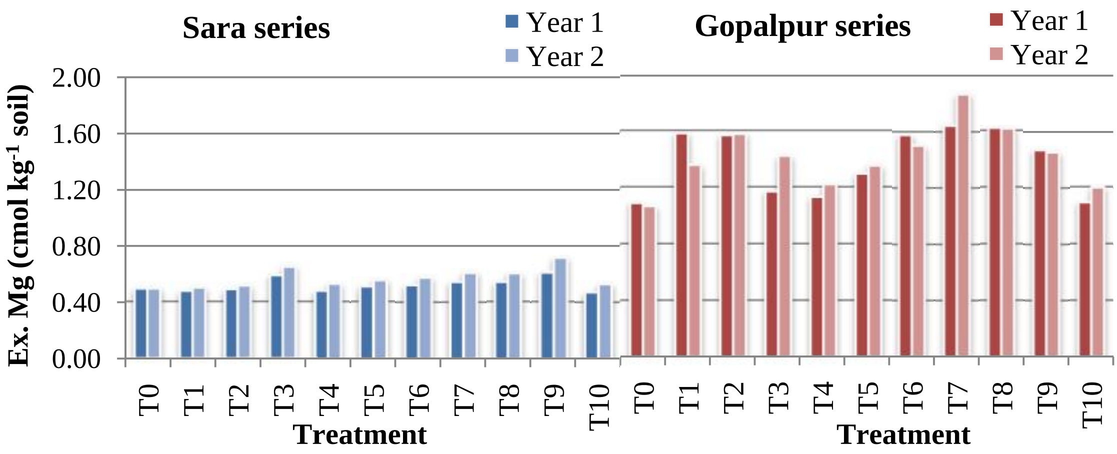

Figure 4.17. Ammonium acetate extractable Mg content in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.17 shows that the ammonium acetate extractable Mg content was higher in organic manure treated soils than that of only chemical fertilizer treated soils. Ammonium acetate extractable Mg contents in soils were increased slightly in all cases compared to the initial values in both the soils. Ayoola and Makinde (2009) concluded after two years of application and cropping that enriched poultry manure increased soil Mg content. The findings of Ayoola and Makinde (2009) were similar to the results obtained in this study.

4.1.2.5.9. Plant Available Iron (Fe) Content in Soils

Appendices 4.5a and 4.5b showsthe influence of chemical fertilizer alone or in combination with organic manures on the available iron (Fe) content in soils. There was significantvariation in Sara series under Jute - T. aman - Mustard cropping patternbutnon-significant variation was found in Gopalpur series under Jute - T. aman - Lentil cropping pattern in two years of study.

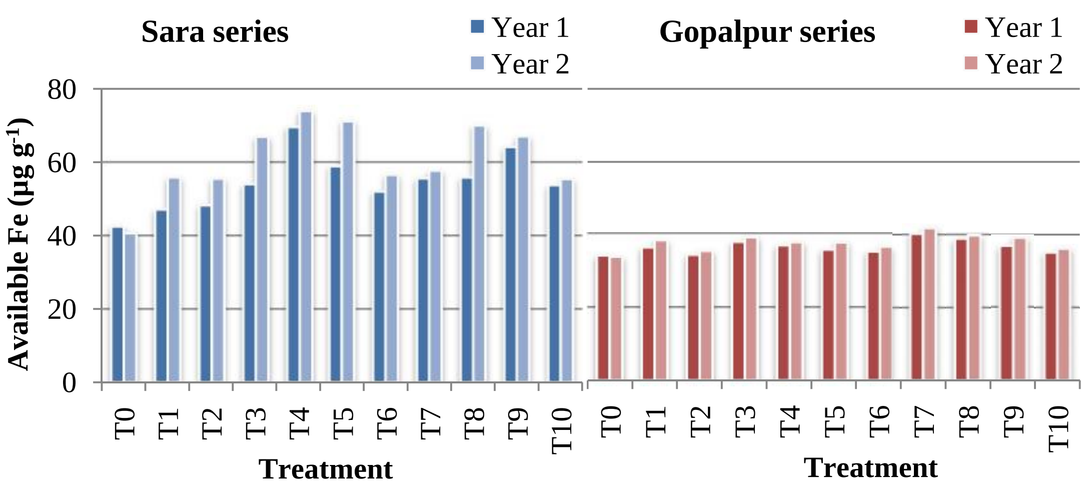

Figure 4.18. Available Fe content in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.18 showsthat the available Fe content was higher in fertilizer + manures treated soils than that of only chemical fertilizer treated soils.In Sara series, the highest available Fe content observed in plots treated with chemical fertilizers and poultry manure, whereas the highest value found with chemical fertilizers and cow dung treated soils in Gopalpur series.The results found in the study was supported by the findings of Mann *et al.* (2006). They reported that micronutrient availability increased with the continuous use of farmyard manure. The increase in available Fe content of soils due to the application of organic manures was also agreed well with this findings of Schlegel (1992), Nayyar and Chhibba (2000) and Singh *et al.* (2000).

4.1.2.5.10. Plant Available Manganese (Mn) Content in Soils

Data presented in Appendices 4.5a and 4.5b show that available manganese (Mn) content in soils did not differ significantly due to application chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake. The available Mn content in soils, however, increased each of two years compared to the initial Mn content (26.91 µg g^{-1}) except T_6, T_7 and T_9 treatments.

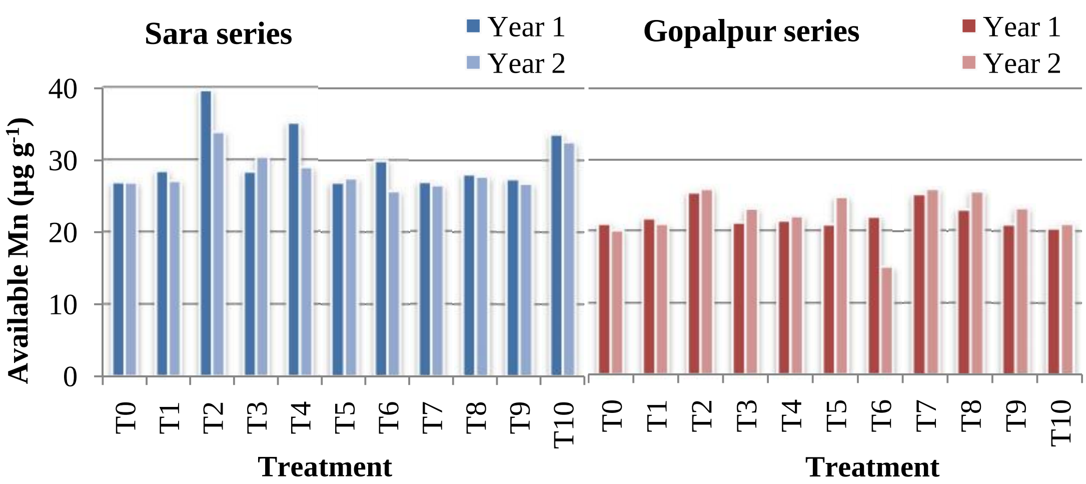

Figure 4.19. Available Mn content in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.19 clearly showsthat the addition of organic manures had no remarkable influence on the available Mn content of both soils during two years of experiments. Mann *et al.* (2006) reported that micronutrient availability increased with the continuous use of farmyard manure. Nayyar and Chhibba (2000) and Singh *et al.* (2000) also reported that the Mn content was significantly increased with the incorporation of organic manures. Considerable variation in Mn content in this study was not found because of short term of the experiment.

4.1.2.5.11. Plant Available Zinc (Zn) Content in Soils

Available zinc (Zn) content in soils increased non-significantly due to the application of different treatments comprising chemical fertilizer and organic manures during two years of experiments with Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patternsexcept Zn content in year one of Sara series. The available Zn content in soils varied from 0.703 to 1.183 µg g^{-1} in Sara series and from 0.893 to 1.162 µg g^{-1} in Gopalpur series during two years of experiments (Appendices 4.5a and 4.5b). The available Zn content was higher in soils treated with only chemical fertilizer treatments than that of combined application of chemical fertilizer + organic manures.

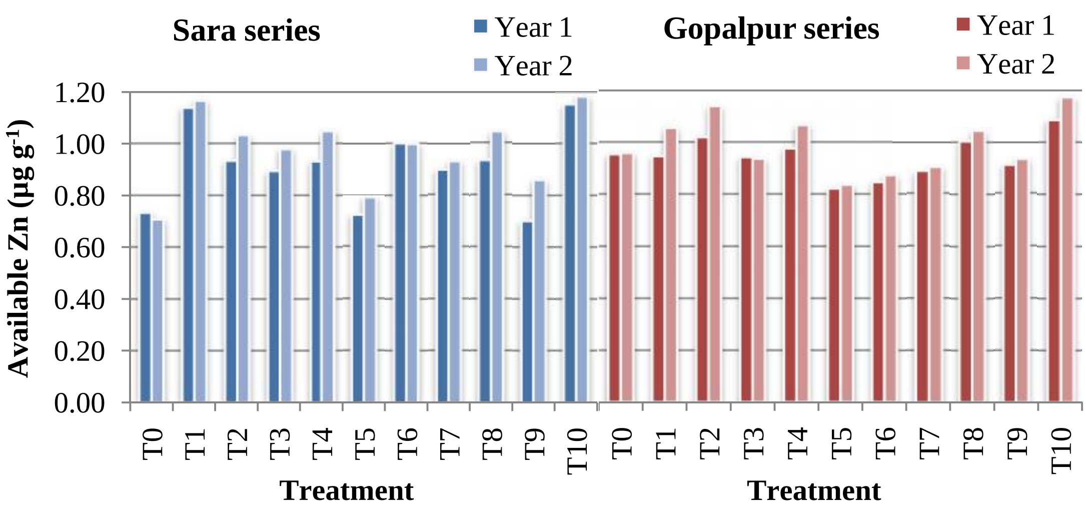

Figure 4.20. Available Zn content in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.20 shows that the higher values of available Zn were obtained by the T_1, T_2, T_6 and T_{10} treatments where soils were treated with fertilizers applied by farmers, recommended fertilizer dose and soil test based fertilizers application in both Sara and Gopalpur series. The lowest values were obtained by T_5 treatment where soils were treated with chemical fertilizer + oilcake. The results of the study indicated that the organic manures had no influence on Zn content of soils due to the application of reduced level of Zn fertilizer with organic manures. Continuous application of farmyard manure in soils increased the availability of micronutrients reported by Mann *et al.* (2006). Singh *et al.* (2000) found that the DTPA-extractable zinc (Zn) increased with the incorporation of organic amendments.

4.1.2.5.12. Plant Available Copper (Cu) Content in Soils

The available copper (Cu) contents in soils of Sara and Gopalpur series underJute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns werenon-significantly influenced by the application of chemical fertilizers alone or in combination with organic manures (Appendices 4.5a and 4.5b).The available Cu content in soils treated combinedly with chemical fertilizer and cow dung, poultry manure and oilcake was higher than only chemical fertilizer treated soils.

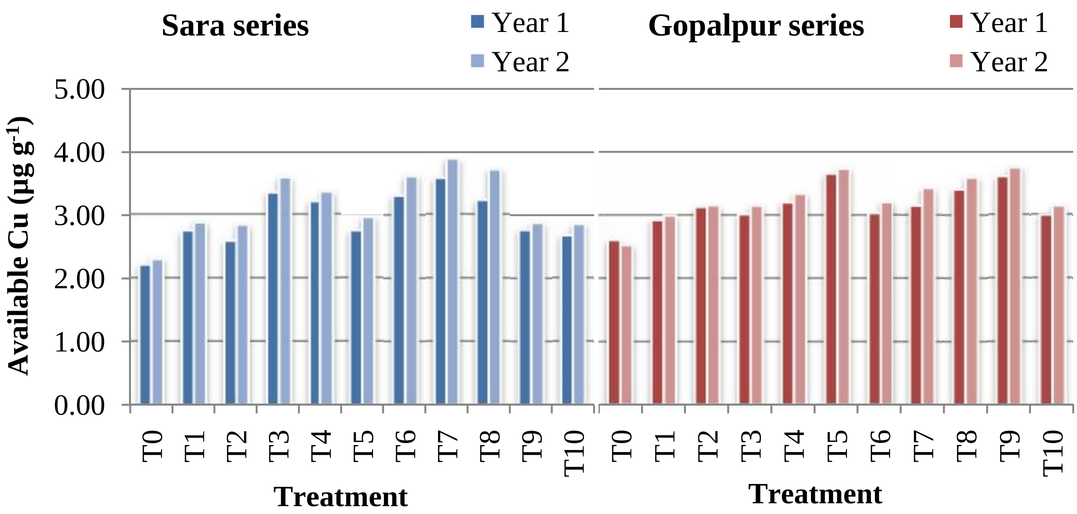

Figure 4.21. Available Cu content in soils of Sara and Gopalpur series as influenced by nutrient management and intensive cropping.

Figure 4.21 shows that the available Cu content in soils of Sara and Gopalpur series was increased in the second yearcompared to first year of experiment due to the application of different treatments. The bars representing different treatments in Sara series did not show any trend in the change of Cu content. On the other hand, the longer bars indicated that the application of chemical fertilizer + organic manures increased the available Cu content in Gopalpur series.The result indicated that the various treatments comprising chemical fertilizers and organic manures had little or no influence on the available Cu content in soils.Mann *et al.* (2006) noticed that micronutrient availability increased with the continuous use of farmyard manure.

The nutrient management practices had significant effect on soils fertility status of both Sara and Gopalpur series. The available nutrients were significantly higher under organic manures and chemical fertilizer based nutrient management practices compared to only chemical fertilizers (fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers) based nutrient management practices. In addition to that, there was declining trend of available nutrients under fertilizers applied by farmers or recommended fertilizers or soil test based nutrient management practices. The organic manures and chemical fertilizers based nutrient management practices also significantly increased the organic matter content in soils. The organic sources affected soil fertility and the C and N mineralization capacities of the soil, which determines the availability of plant nutrients. Continuous application of manures with chemical fertilizers increased the levels of N, P, K, S, Ca and Mg in the soil even under intensive cropping for two years. Thus, organic matter creates a reservoir of soil nutrients due to several years of their application, and the use of cow dung, poultry manure and oilcake enhanced the transformation of nutrients to available form. The above results indicated that appropriate nutrients management and soil conservation under intensive cropping like Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns may be possible through ensuring continuous supply of organic matter.

4.2. Effect of Management Practices and Intensive Cropping onCrop Yield

The investigationwas conducted for observing the effect of nutrient management practices through chemical fertilizers alone or in combination with organic manures and intensive cropping on the yield of crops over two years underJute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns in Sara and Gopalpur series, respectively.

4.2.1. Yield of Crops in Jute - T. aman – Mustard Cropping Pattern

Three crops based pattern Jute - T. aman – Mustard were used to increase cropping intensity in the field experiment in Sara series at Paranpur village for two consecutive years.

4.2.1.1. Effect on Jute Yield

4.2.1.1.1. Effect on Fibre Yield of Jute

The chemical fertilizer + organic manure (cow dung, poultry manure and oilcake) treatments significantly influenced the fibre yield of jute (*Corchorus olitorius* L.) cv. BJRI Tossa-2 (Appendix 4.6).The fibre yield of jute varied from minimum 2.72 t ha^{-1} with T_0 treatment to maximum 4.91 t ha^{-1} with T_9 treatment in the first year. In the second year, the lowest fibre yield of 2.76 t $ha^{-1}$was found with T_0 treatment (control) and the highest fibre yield of 4.98t $ha^{-1}$was observed with T_9 treatment (75% of recommended fertilizers + 2 t ha^{-1} oilcake) which was statistically identical to T_8 treatment but dissimilar to rest of the treatments. The fibre yield of jute was increased in the second yearcomparedto the fibre yield in the first year.The application of different treatments to soils resulted in 42.65 - 80.51% fibre yield increase over control,where the increase was highest with T_9treatment.(Appendix 4.6 and Figure 4.22).

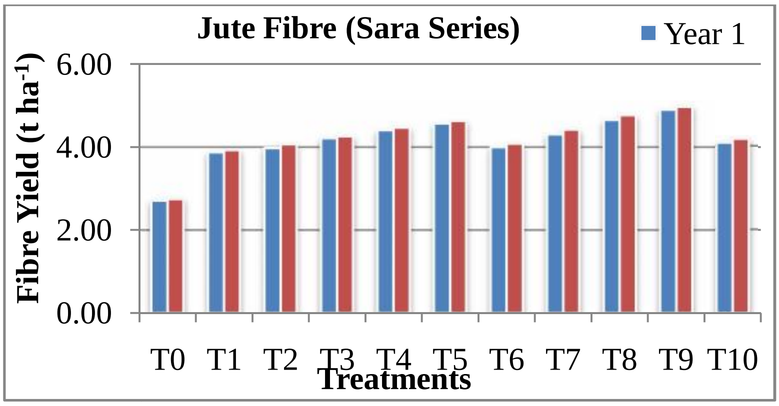

Figure 4.22. Fibre yield of jute under Jute - T. aman – Mustard cropping pattern in Sara series as influenced bydifferent treatments.

The fibre yield of jute obtained from different treatments applications after two years can be ranked in the following order: T_9> T_8> T_5> T_4> T_7> T_3> T_{10}> T_6> T_2> T_1> T_0(Fig 4.22 and Appendix 4.6). The effect of 75% of recommended chemical fertilizers + oilcake (T_9) treatment was statistically superior not only to the chemical fertilizers + poultry manure and chemical fertilizers + cow dung treatments but also to the rest of the treatments. It is clear from the graph that the combined application of chemical fertilizer and oilcake significantly produced highest fibre yield than that of the other treatments.The combination of chemical fertilizer and organic manures resulted in higher production of jute was also reported by Ray *et al.* (2000) in jute - rice - wheat cropping system, Kumar *et al.* (2010) in jute - rice cropping system.

4.2.1.1.2. Effect on Stick with Bark Yield of Jute

The application of different treatments significantly influenced theyields of jute stick with bark. The stick with bark yield obtained from different treatments ranged from9.60 to 14.55 t ha^{-1}in two years of field experiments(Appendix 4.6). In the first year, the highest yield of 14.27 t ha^{-1} was recorded with T_9 treatment receiving 75% of recommended fertilizers + 2 t ha^{-1}oilcake and the lowest yield of 9.61 t ha^{-1}was noted with control receiving no fertilizer or manure. In the second year, the jute stick with barkyield wereranged between 9.60 t ha^{-1}with T_0 treatment and 14.55 t ha^{-1}with T_9 treatment(Fig 4.23 andAppendix 4.6). The jute stick with bark yield with T_9 treatment was statistically identical to T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) and T_5 (75% farmers' practice + 75% recommended S&B + 2 t ha^{-1} oilcake) treatments but different from the rest of the treatments.

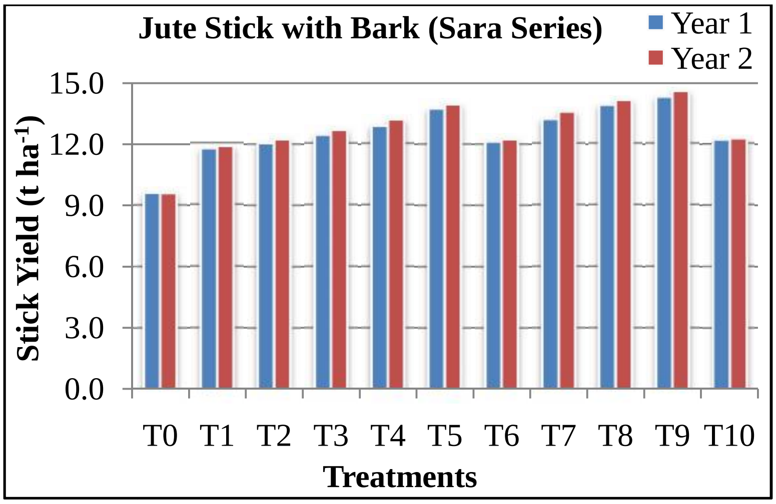

Figure 4.23. Stick yield of jute under Jute - T. aman – Mustard cropping pattern in Sara series as influenced by nutrient management.

Figure 4.23 showsthe data on highest yield of stick with bark in plots treated combinedly with chemical fertilizer andcow dung, poultry manure and oilcake over only chemical fertilizer treated plotsor control plots. On the basis of decreasing yield of stick with bark, the treatments may be arranged in the following order:T_9> T_8> T_5> T_7> T_4> T_3> T_2> T_{10}>T_6> T_1> T_0. Annos (2000) reported increased stick yield of jute with increased N application.

4.2.1.2. Effect on Rice Yield

4.2.1.2.1.Effect on Grain Yield of Rice

The grain yield of T. aman rice(*Oryza sativa* cv. BRRI dhan39)in Sara series was significantly influenced by the application of different treatments during two years offield experiments(Appendix 4.6). In the first year, the grain yield of rice varied from 1.94 t $ha^{-1}$with T_0 treatment receiving no fertilizer or manure to 4.48 t $ha^{-1}$with T_9(75% of recommended fertilizers + 2 t ha^{-1}oilcake) treatment. In the second year, the grain yield of rice was lowest 1.98 t ha^{-1} with T_0 treatment receiving no fertilizer and was highest 4.57 t ha^{-1} with T_9 treatment, which was statistically similar to T_4, T_5 T_7 and T_8 treatments but dissimilar to rest of the treatments. The grain yield of rice increased in the second yearcompared to the yield offirst year, and the highest increase in grain yield was 130.73% withT_9 treatment over control. The rice grain yield with chemical fertilizers + oilcake treatment was statistically identical to the chemical fertilizers + poultry manure or cow dung treatments. With respect to grain yield of rice during two years period, the response of crops to different treatments were of the following order: T_9> T_5> T_4> T_8> T_7> T_3> T_6> T_2> T_1> T_{10}> T_0 (Figure 4.24 and Appendix 4.6).

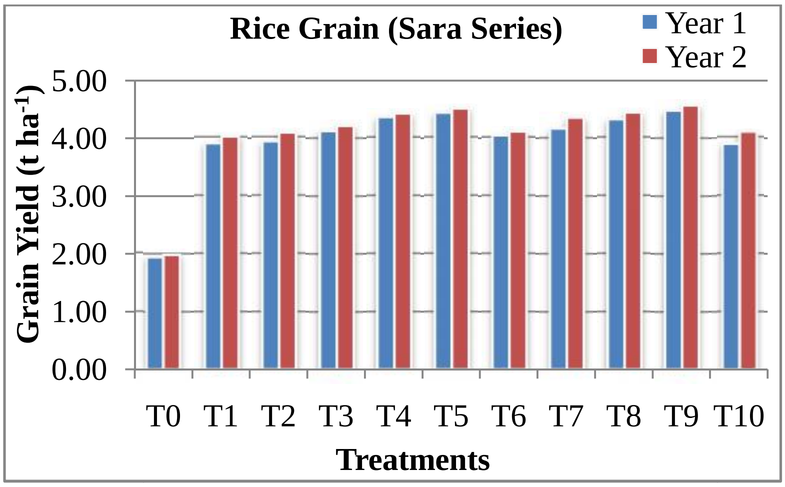

Figure 4.24. Grain yield of rice under Jute - T. aman- Mustard cropping pattern in Sara series as influenced bydifferent treatments.

The results indicated that the higher yield of rice can be achieved with the combined application of chemical fertilizers and oilcake treatment andthe treatment was more effective in producing rice grain than other treatment combinations. Kang and Balasubramanian (1990) also found that high and sustained crop yields could be obtained with judicious and balanced NPK fertilization combined with organic matter amendments. Similar effect of poultry manure was reported by Maskina *et al.* (1988)and Rahman *et al.* (2009)reported that poultry manure increased the yield of rice grain which was 2.6 times higher than that with cattle manure (37%). Saleque *et al.* (2004) stated that poultry manure might be a good source of organic matter and nutrients for rice production. The finding of the present experiments are in agreement with those of Reddy *et al.* (2005), Barik*et al.* (2006), Kumawat*et al.* (2006), Pal *et al.* (2006), Urkurkar*et al.* (2010), Rahman *et al.* (2012), Islam *et al.* (2014) andSarker*et al.* (2015).

4.2.1.2.2. Effect on Straw Yield of Rice

The application of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake significantly influenced the straw yield of rice (Appendix 4.6). Data on straw yield revealed significant variation due to treatment variation during two years of field experiments. The highest straw yield (6.22 t ha^{-1}) was found with T_9 treatment receiving 75% of recommended fertilizers and 2 t ha^{-1} oilcake,which was statistically identical to T_3, T_4, T_5 T_7 and T_8 treatments but dissimilar to rest of the treatments. The second highest (6.11 t ha^{-1}) and third highest (6.05 t ha^{-1}) straw yields were observed with chemical fertilizers + oilcake (T_5)treatment and with recommended fertilizers +poultry manure (T_8) treatment, respectively. The lowest straw yield (3.46 t ha^{-1}) was recorded with T_0 (control) treatmentin two years.

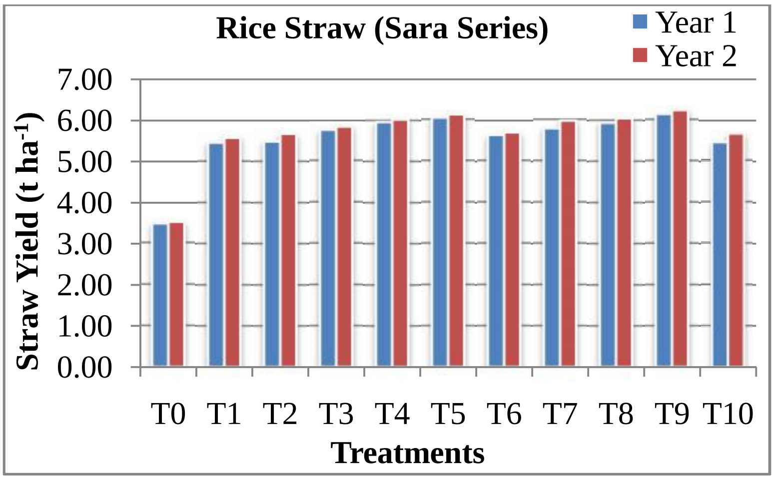

Figure 4.25. Straw yield of rice under Jute - T. aman – Mustard cropping pattern in Sara series as influenced by different treatments.

The straw yields in the second year were higher for all the treatments compared to the yield of first year of experiment (Figure 4.25 and Appendix 4.6). The straw yields obtained from different treatments can be ranked in the order of T_9> T_5> T_8> T_4> T_7> T_3> T_6> T_2> T_{10}> T_1> T_0.The data revealed that the application of chemical fertilizers along with oilcake (T_5 and T_9) brought about significant improvement in straw yield and established superiority over the application of chemical fertilizer alone or in combination with cow dung and poultry manure or control (Figure 4.25).The higher straw yield obtained with the application of organic manures especially oilcake might be in harmony with supply of nutrients at a rate sufficient to support growth and yield. Vanaja and Raju (2002) reported that different combinations of chemical fertilizers with organic manure produced the highest grain and straw yields. Rahman *et al.*(2009) observed that the application of organic manure and chemical fertilizers increased the grain and straw yields of rice.It was found that organic manure in combination with chemical fertilizers increased straw yield. The similar results were observed by Barik*et al.* (2006), Biswas *et al.* (2009), Chandra *et al.* (2001), Kumawat*et al.* (2006) and Urkurkar*et al.* (2010).

4.2.1.3. Effect on Mustard Yield

4.2.1.3.1.Effect on Grain Yield of Mustard

Data on grain yield of mustard (*Brassica napus*L. cv. Rai-5) were influenced significantly by different treatments appliedtosoils of Sara series during two years' of field experiments (Appendix 4.6). In the first year, the maximum grain yield of 1.45 t ha^{-1} was recorded withT_9 treatment receiving 75% of recommended fertilizers+ 2 t ha^{-1} oilcake, which was statistically identical to and closely followed by T_8 (75% of recommended fertilizers+ 3 t ha^{-1} poultry manure) and T_{10} (soil analysis based treatment) treatments. The grain yield was 174.62% higher compared to the lowest grain yield (0.53 t ha^{-1}) ofT_0 treatment (control). The treatment T_1 (chemical fertilizers applied by farmers) and T_2 (chemical fertilizers applied by farmers+ recommended S & B) produced lower grain yield of mustard than the plots receiving both chemical fertilizers and organic manures. In the second year, the grain yield of mustard decreased compared to the yield of first year with all treatments except control. The highest grain yield (1.43 t ha^{-1}) was obtained with T_9 treatmentwhich was 167.23% higher compared to the control treatment (Figure 4.26 and Appendix 4.6). The effect of recommended fertilizers + oilcake was statistically identical to recommended fertilizers + poultry manure or cow dung and soil test based treatments but superior to the other treatments.

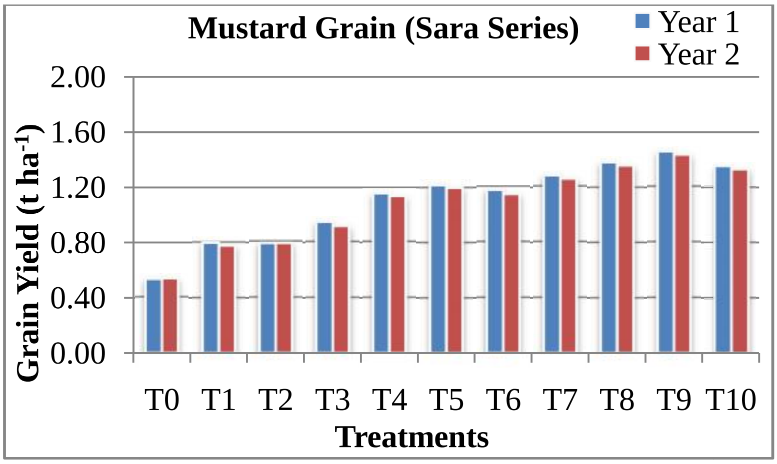

Figure 4.26. Grain yield of mustard under Jute - T. aman – Mustard cropping pattern in Sara series as influenced bydifferent treatments.

The grain yield of mustard obtained from different treatments can be ranked in the following order: T_9> T_8> T_{10}> T_7> T_5> T_6> T_4> T_3> T_2> T_1> T_0(Figure 4.26). The combined use of chemical fertilizer and oilcake produced the highest mustard grain in both years. Thus, mustard performed best in terms of yield with complementary application of chemical fertilizer and oilcake. The cause of yield increase might be due to higher nutrient consumption and favorable effect on yield contributing characters of mustard. Murwira and Kirchman (1993) observed that nutrient use efficiency might be increased through the combination of manures and mineral fertilizer. Zamil *et al.* (2004) found higher mustard grain and stover yield due to the application poultry manure than cow dung.The finding is also in agreement with those of Rasool *et al.* (2013).

4.2.1.3.2. Effect on Stover Yield of Mustard

Data presented in Appendix 4.6 show that the stover yields of mustard were significantly affected by different treatments. The stover yield ranged from 2.63 to 3.95 t ha^{-1}in the first year and from 2.51 to 4.52 t ha^{-1}due to application of different treatments in the second year(Figure 4.27 and Appendix 4.6). The highest stover yield (3.95 t ha^{-1}) was obtained from the plots receiving 75% of farmers' practice + recommended S & B + 2 t ha^{-1}oilcake(T_5) and the lowest yield (2.51 t ha^{-1}) from the control plots (T_0).The combined application of chemical fertilizers and oilcake i.e. T_5treatment recorded the yield of 3.95 t ha^{-1}in the first year and 4.52 t ha^{-1}in the second year, showing yield increase of 50.11 - 79.89% over control. The results showed that stover yields decreased in the second years compared to the yields in the first yearwith all the treatments except T_5 treatment. The effect of recommended chemical fertilizers + oilcake treatment was statistically dissimilar to all other treatments.

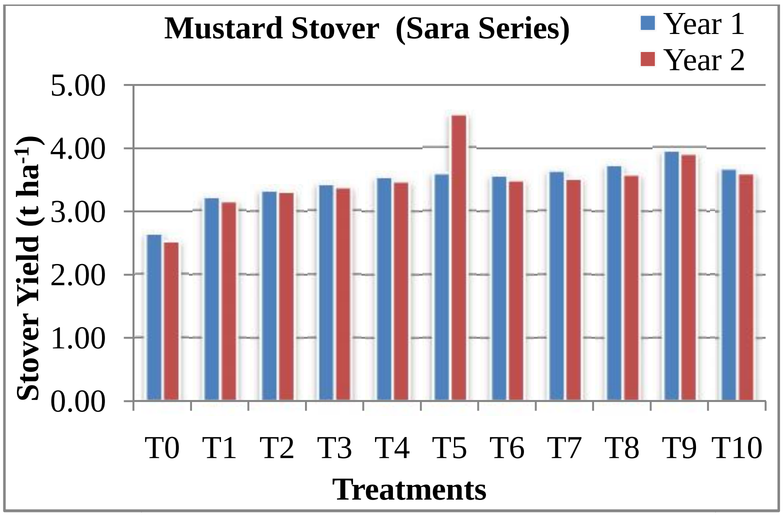

Figure 4.27. Stover yield of mustard under Jute - T. aman – Mustard cropping pattern in Sara series as influenced by different treatments.

According to the results of stover yield, the treatments were arranged in the following order:T_5>T_9> T_8> T_{10}> T_7> T_6> T_4> T_3> T_2> T_1> T_0 (Figure4.27). These results revealed that the combined application of chemical fertilizers and oilcake were more effective than other treatments for continuous supply of nutrients to crops.The cause of yield increment might be due to higher nutrient consumption and favorable effect on yield contributing characters of mustard. These results are in conformity with that of Kansotia *et al.* (2015) who observed increased seed yield of mustard through application of different rates of vermicompost. Mohiuddin *et al.* (2011) reported that the seed and stover yield increased with increasing N level. Zamil *et al.* (2004) found higher grain and stover yieldsof mustard due to the application poultry manure than cow dung.

4.2.2.Jute - T. aman – Lentil Cropping Pattern

Three crops based cropping pattern,Jute - T. aman – Lentil was introduced for consecutive years to increase cropping intensity in the field experiment at Tilchara village,the soil was of Gopalpur series.

4.2.2.1. Effectof Treatments on Jute Yield

4.2.2.1.1. Effect on Fibre Yield of Jute

The fibre yields of jute (*Corchorus olitorius* L.)were significantly influenced by the application of chemical fertilizersalone or in combination with organic manures during two years of experimentsunder Jute - T. aman – Lentil cropping pattern (Appendix 4.7).In the first year, the highest fibre yield of 4.82t $ha^{-1}$was recorded for jute when it was treated combinedly with recommended chemical fertilizers and oilcake (T_9treatment), and the lowest yield of 2.67 t ha^{-1} was noted with T_0 treatment receiving no fertilizer or manure. In the second year, similar trend of results was also observed. The fibre yield of jute varied between the lowest 2.66 t ha^{-1}which was recorded withT_0 treatment and the highest jute fibre yield of 5.01t $ha^{-1}$was found with T_9 treatment, which was statistically identical to T_5 treatment but dissimilar to rest of the treatments. The highest yield was 88.23% higher over control(Appendix 4.7 and Figure 4.28).The significantly second highest value of fibre was also found with T_5 treatment receiving 75% of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake in both the years. The results revealed that the effect of combined application of chemical fertilizers and organic manures created better performance than that of only chemical fertilizersi.e. fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers. Among the combined application of chemical fertilizers and organic manures, the effect of chemical fertilizers + oilcake treatment was significantly different from the rest two combinations i.e. chemical fertilizers + poultry manure and chemical fertilizers + cow dung treatments.

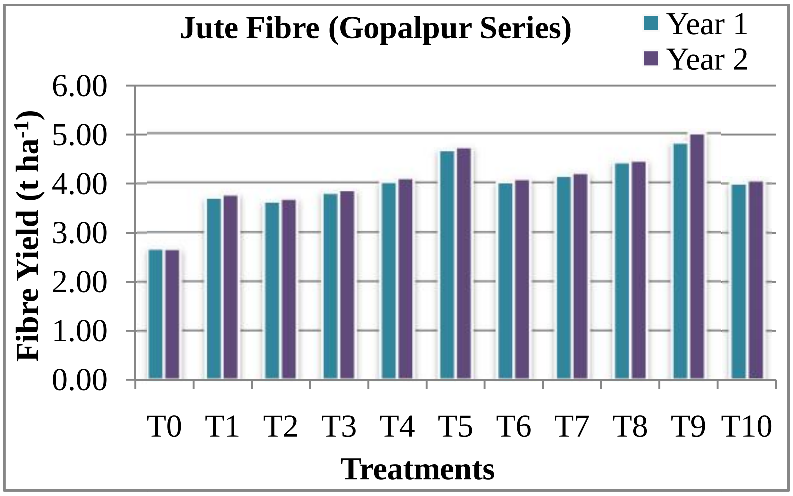

Figure 4.28. Fibre yield of Jute under Jute - T. aman – Lentil cropping pattern in Gopalpur series as influenced by different treatments.

Results indicated that the highest fibre yield of jute was achieved when the plots were treated with chemical fertilizer and oilcake. The effect of different treatments on fibre yield of jute may be ranked in the following order: T_9> T_5> T_8> T_7> T_4>T_{10}>T_6> T_3> T_2> T_1> T_0which means OC+CF >PM+CF >CD+CF > CF > CON (Appendix 4.7 and Figure 4.28).The combination of chemical fertilizer and organic manures resulted in higher production of jute, which was also reported by Ray *et al.* (2000) in jute - rice - wheat cropping system;Kumar*et al.* (2010) in jute and Singh*et al.* (2011) in mesta - rice cropping system.

4.2.2.1.2. Effect on Stick with Bark Yield of Jute

The stick plus bark yields of jute (*Corchorus olitorius* L.) during two years' of field experimentsin Gopalpur series soils as influenced by various treatments are given in Appendix 4.7. The different treatments createdsignificant effects on the stick with bark yield of jute. The stick with bark yields were ranged from 9.40 to 14.05 t $ha^{-1}$and 9.37 to 14.38 t ha^{-1} in the first and second years, respectively (Appendix 4.7 and Figure 4.29). The highest yield of both years was found with T_9 (75% of recommended fertilizers+ 2 t ha^{-1}oilcake)treatment whose effect was statistically identical to T_5 (75% of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake) and T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment but superior to the rest of the treatments. The lowest stick yield of 9.37 t ha^{-1} was recorded with the control (T_0) treatment where neither fertilizers nor manures were applied for last two years. Highest 39.58% stick yield increase was foundwith T_9 treatment over control. The jute stick with bark yields were increased in the second year than that of the first year due to the application of different treatments.

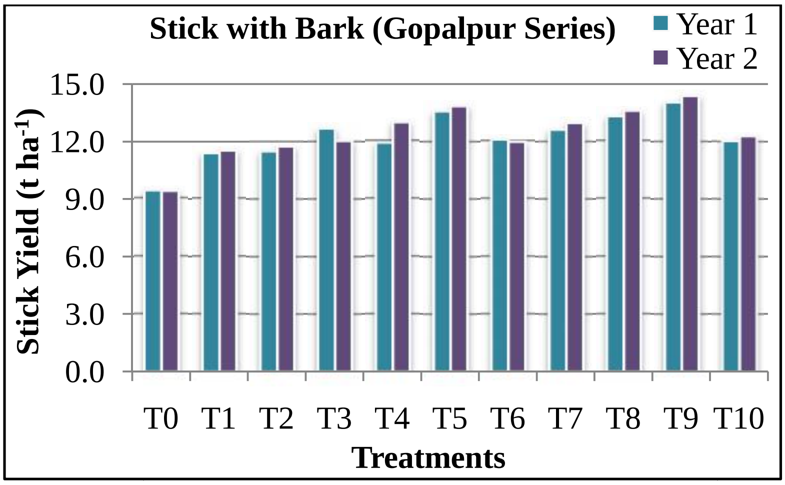

Figure 4.29. Stick yield of Jute under Jute - T. aman – Lentil cropping pattern in Gopalpur series as influenced by different treatments.

Results indicated that the combined application of chemical fertilizers and organic manures (cow dung, poultry manure and oilcake) provided more stick yield than when only chemical fertilizers(fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers) were applied or with control. The decreasing order of stick yield was T_9> T_5> T_8> T_4> T_7>T_3> T_{10}>T_6> T_2> T_1> T_0(Figure 4.29).Alam (1992) reported that stick yield of jute increased with increasing level of N fertilizers and was highest with 200 kg N ha^{-1}. Similar results were also reported by Annos, 1986 and Ahmed *et al.*, 1999.

4.2.2.2. Effect of Treatments on Rice Yield

4.2.2.2.1. Effect on Grain Yield of Rice

The effects of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake on the yield of T. aman (BRRI dhan39) rice grown in Gopalpur series were significant (Appendix 4.7). In the first year,the highest grain yield of 4.48 t $ha^{-1}$was found with T_9 treatment receiving 75% of recommended fertilizers+ 2 t ha^{-1}oilcake and the lowest grain yield of 2.18 t ha^{-1} was noted with T_0(control) treatment.In the second year, the experimental plot treated with recommended chemical fertilizersandoilcake designated as T_9 treatment produced the highest grain yield of 4.54t ha^{-1}, which showed 109.75% yield increase over control. The lowest grain yield of2.16 t $ha^{-1}$was found with T_0(control) treatment (Appendix 4.7 and Figure 4.30). The effect of recommended fertilizers + oilcake (T_9) treatment was statistically similar to all the treatments except T_0(control), T_1 (farmers' practice) and T_6 (recommended fertilizer nutrients) treatments.

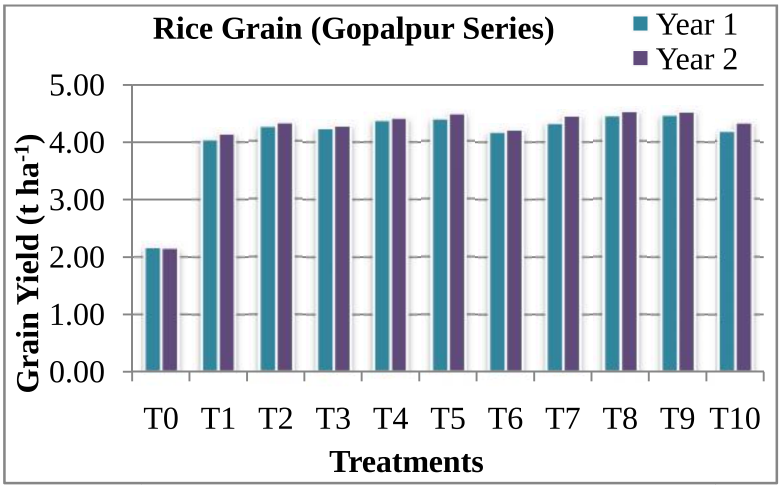

Figure 4.30. Grain yield of rice under Jute - T. aman – Lentil cropping pattern in Gopalpur series as influenced by different treatments.

The combined application of chemical fertilizers and oilcake provided the highest grain yield than other treatments which might ensure the continuous supply of sufficient nutrients to support the growth of crops. The grain yield of rice may be ranked in the following order: T_9>T_8>T_5> T_4> T_7>T_2>T_3>T_{10}>T_6> T_1> T_0. The order indicated that the lowest grain yields were found with those treatments where only chemical fertilizer was used such as T_1, T_2, T_6 and T_{10} treatments (Appendix 4.7 and Figure 4.30). Results of grain yield indicated that high yield of rice can be achieved with maximum supply of nutrients throughout the growing period. The combination of inorganic and organic fertilizers resulted in higher productivity of rice, was also reported by Ray *et al.* (2000) in jute - rice - wheat cropping system. Gupta (1995) also reported the highest yield of rice with the combined application of poultry manure and phosphorus fertilizer. The finding is in agreement with those of Meelu and Morris (1984), Rao and Moorthy (1994) and Sarker*et al.* (2015).

4.2.2.2.2. Effect on Straw Yield of Rice

Results on straw yield of rice under different treatments recorded in two years of field experiments under Jute - T. aman - Lentil cropping pattern are presented in Appendix4.7.The combined application of chemical fertilizers and organic manures (cow dung, poultry manure and oilcake) significantly increased the rice straw yield over the application of only chemical fertilizers(fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers) or control (T_0). The straw yields of rice varied from 2.18t $ha^{-1}$with T_0(control) treatment to 4.45 t ha^{-1} with T_8(75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment in the first year and from 2.16 t ha^{-1} with T_0 treatment to 4.52 t $ha^{-1}$with T_8 treatment in the second year. Application of chemical fertilizers in combination with poultry manure (T_8) induced significant improvement on rice straw yield over rest of the treatments. The second highest straw yield (4.48 t ha^{-1}) in the second year was recorded with T_5 treatment, which was significantly higher over rest of the treatment combinations except the superior one as stated (Appendix 4.7 and Figure 4.31).

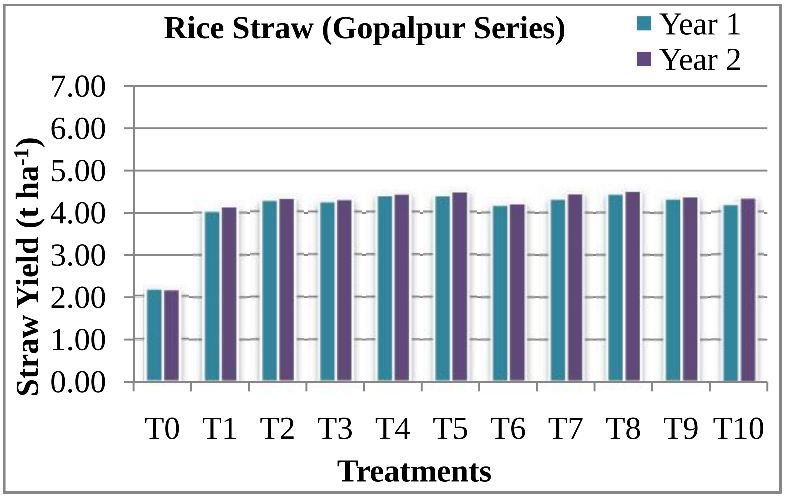

Figure 4.31. Straw yield of rice under Jute - T. aman – Lentil cropping pattern in Gopalpur series as influenced by different treatments.

Figure 4.31shows that the combined application of chemical fertilizer and poultry manure played major role in providing the highest straw yield of rice over other treatments. In all cases the straw yield increased in the second year than that of first year under Jute - T. aman – Lentil cropping patternwas observed with the only exception withcontrol (T_0) treatment, which produced lower straw yield in second year compared to the first year. The straw yield of rice under different treatments in decreasing order was as follows: $T_8 > T_5 > T_7 > T_4 > T_9 > T_2 > T_3 > T_{10} > T_6 > T_1 > T_0$. The reason for increased straw yield of rice over control was probably due to the residual effect of combined application of cow dung, poultry manure and oilcake with chemical fertilizers. Vanaja and Raju (2002) reported that different combinations of chemical fertilizers with organic manure produced the highest grain and straw yields. Barik *et al.* (2006) and Rahman *et al.*(2007) reported that straw yield of rice was significantly increased due to residual effect of poultry manure.

4.2.2.3. Effect on Lentil Yield

4.2.2.3.1. Effect on Grain Yield of Lentil

The treatment doses comprised of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake, had significant effects on lentil (*Lens culinaris* L. cv. BARI Masur-2) grain yield (Appendix 4.7). Application of different treatments increased lentil grain yield significantly over the control. The highest grain yield of 1.74 t ha^{-1}) was obtained with T_8(75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment andthe lowest lentil grain yield of 0.91 t $ha^{-1}$was recorded with control (T_0) treatment, where no fertilizer or manure was applied in two years of field experiments. In the first year, the lentil grainproduction with control (T_0) treatment was relatively low (0.94 t ha^{-1}), which was 80.08% lower than that obtained with T_8treatment (1.70 t ha^{-1}). Soils treated with recommended fertilizer dose (T_6) also produced better yield (1.32 t ha^{-1}) compared to the farmers' practice (T_1). Almost all the treatments produced higher yield in the second year compared to that of first year. In the second year, the highest lentil grain yield of 1.74 t ha^{-1} was found withT_8treatment,which wasincreased by 92.60% compared to the control.

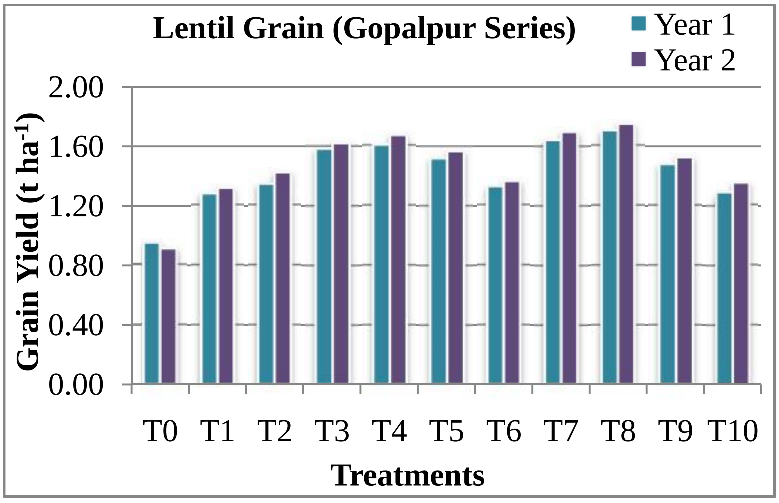

Figure 4.32. Grain yield of lentil under Jute - T. aman – Lentil cropping pattern in Gopalpur series as influenced by different treatments.

The effect of T_8 treatment was statistically identical to T_3, T_4 and T_7treatmentsbut superior to rest of the treatments. The grain yield was generally higher with combined application of chemical fertilizers and organic manures compared to that obtained with chemical fertilizer during two years of experiments (Appendix 4.7 and Figure 4.32).

The grain yield of lentil obtained from different treatments can be ranked in the following order: T_8> T_7> T_4> T_3> T_5> T_9> T_2> T_6> T_{10}> T_1> T_0 (Figure 4.32). The combined use of chemical fertilizer and poultry manure produced highest lentil grain in both the years of experiments. The cause of yield increment might be due to steady supply of nutrients and favorable effect of yield contributing parameters. Murwira and Kirchman (1993) observed that the combined application of chemical fertilizers and organic manures performed better in terms of yield of lentil grain. The finding is in agreement with those of Maitra *et al.* (2008), Deo and Khaldelwal (2009), Bhuiyan *et al.* (2011) and Tripathi *et al.* (2011).

4.2.2.3.2. Effect on Stover Yield of Lentil

The stover yield of lentil (*Lens culinaris*L.) was also significantly affected by the application of different treatments like lentil grain yield (Appendix 4.7). In the first year, the highest and lowest stover yields were 1.72t ha^{-1} and 1.23 t ha^{-1}, were found with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) and T_0 (control) treatment, respectively. In the second year, the stover yield of lentil varied from 1.19 to 1.73 t ha^{-1} wherethe lowest stover yield of lentil was observed with T_0 treatment and the highest with T_8 treatment whose effect was statistically identical to, , T_7 and T_9 treatments (Appendix 4.7 and Figure 4.33). The effect of recommended fertilizers + poultry manure (T_8) treatment was statistically identical to 75% of farmers' doses + 75% of recommended S&B + 3 t ha^{-1} recommended poultry manure (T_4), 75% of farmers' doses + 75% of recommended S&B + 2 t ha^{-1} recommended oilcake (T_5) recommended fertilizers + cow dung (T_7) and recommended fertilizers + oilcake (T_9) treatments but superior to the rest of the treatments.

Figure 4.33 shows that the stover yield of lentil was considerably higher in T_8 treatment comprised of chemical fertilizer and poultry manure compared to other treatments. Almost all stover yields increased in the second year compared to first year due to the application of different treatments except control. With respect to stover yield of lentil during two years period, the response of lentil to different treatments may be arranged in the following

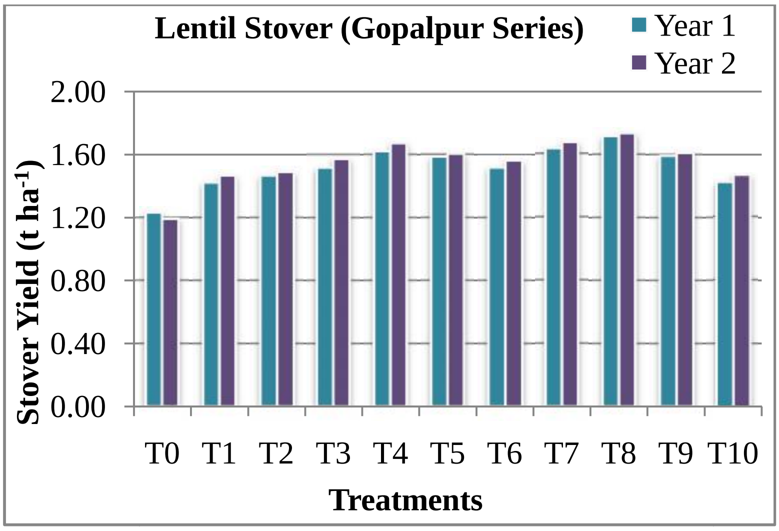

Figure 4.33. Stover yield of lentil under Jute - T. aman – Lentil cropping pattern in Gopalpur series as influenced by different treatments.

order: CF+PM > CF+CD > CF+OC > CF > CON. Similar result was obtained by Murwiraand Kirchman (1993), Singh and Singh (2004),Deo and Khaldelwal (2009)and Tripathi *et al.*(2011).

The experimental results suggested that 75% of recommended chemical fertilizers + oilcake (T_9) treatment can be applied for better growth and yield of jute, rice and mustard, which was followed by 75% of recommended chemical fertilizers + poultry manure (T_8) and 75% of recommended chemical fertilizers + cow dung (T_7) treatments. But 75% of recommended chemical fertilizers + poultry manure (T_8) can be applied for producing significantly higher yields of lentil. The results of these experiments give a clear indication that the yields of crops were increased due to the combined application of chemical fertilizers and organic manures than that of recommended fertilizers or farmers' practice or control treatments. It is also found from the experiments that the combined use of chemical fertilizers and organic manures can supply sufficient nutrients for the crops.The organic manures added organic matter to the soils which acted as a reservoir for plant nutrients as well as nutrient buffering material. Results showed that jute, rice and lentil performed better in terms of yield with treatment comprised of chemical fertilizers and organic manures. But the mustard did not performed well with any treatments when considered the yields after two years of field experiments. It might due to that nutrients were supplied to crop at rates below crop requirements. It had become evident that the effect of organic manures and chemical fertilizers on crops yields was largely due to all plant nutrients it supplied in addition to other favourable effects created by them.

4.3. Nutrient Concentrationin Crops

The nutrients concentration in crops under Jute - T. aman - Mustard and Jute - T. aman – Lentil cropping patternswere different because of their physiological requirements of a particular nutrient. The N, P, K, S, Zn and B concentrations in jute, rice, mustard and lentilwere calculated and found within the range of concentration of each nutrient which was reported by a number of scientists mentioned in the literature review chapter.

4.3.1. Nutrients Concentration in Jute

The application of different treatments significantly influenced the N, P, K, S, Zn and B concentrations in stick plus bark of jute (*Corchorus olitorius* L.) cv. BJRI Tossa-2 except Zn concentration in Sara series soil. The concentrations of N, P, K, S, Zn and B varied from 0.47 to 0.99%, 0.09 to 0.24%, 0.83 to 1.94%, 0.10 to 0.22%, 11.52 to 28.70 µg $g^{-1}$and 15.17 to 38.83 µg g^{-1}due to application of different treatments in Sara and Gopalpur series, respectively. The highest N, K, S and Zn concentrations in jute stick with bark were observed with treatment receiving recommended fertilizers and cow dung. The application of chemical fertilizers and poultry manure provided highest P and B concentration in jute stick. The lowest concentrations were observed with the controltreatment (Appendices 4.8a, 4.8b, 4.9a and 4.9b).

4.3.2. Nutrient Concentration in Rice

The concentrations of P, S and B of Sara series, and K and S of Gopalpur series in grain and straw of T.aman rice were also significantly affected due to the application of different treatments. The highest N concentrations in rice grain and straw were 1.50% and 0.92% with T_5 treatment (75% of farmers’ practice + 75% of recommended S & B + 2 t ha^{-1} oilcake) and T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure), respectively, in both series soils. The highest concentrations of P, S and Zn in grain and straw were of 0.20% and 0.18%; 0.098% and 0.112%; and 38.79 µg g^{-1} and 59.56 µg g^{-1} found with T_5 treatment during two years of experiments in both series. The maximum K concentrations in grain and strawof 0.27% and 3.48%were obtained withT_8 treatment and the highest B concentrations in grain and straw were 2.31 µg g^{-1} and 1.79 µg $g^{-1}$with T_{10} treatment receiving soil analysis based treatmentand T_8, respectively. The lowest nutrients concentration in grain and straw of rice were found with the control (Appendices 4.10a, 4.10b, 4.11a, 4.11b, 4.12a, 4.12b, 4.13a and 4.13b).

4.3.3. Nutrient Concentration in Mustard

The application of different treatments significantly influenced the nutrient concentrations in grain and stover of mustard under Jute - T. aman - Mustard cropping pattern. In mustard grain, the concentration of N, K and Zn ranged from 1.70 to 3.98%, 0.52 to 0.96% and 21.64 to 44.30 µg g^{-1}, respectively, where the highest value was observed with T_9 (75% of recommended fertilizer nutrients and 2 t ha^{-1} oilcake) treatment in experiments of both years. The P concentration in grain varied from 0.52 to 0.93% and the highest value was found with T_5 (75% of farmers' practice + recommended S&B + 2 t ha^{-1} oilcake) treatment. The S and B concentrations in mustard grain varied from 0.08 to 0.28% and 4.14 to 9.71 µg g^{-1} in both years, where the highest values were yielded with chemical fertilizers only and combination of chemical fertilizers and poultry manure, respectively. In mustard stover, the N, P, K, S, Zn and B concentrations varied from 0.39 to 0.97%, 0.02 to 0.08%, 0.83 to 1.79%, 0.12 to 0.35%, 12.37 to 27.19 µg g^{-1} and 7.28 to 14.58 µg g^{-1} in two years of experiments. The highest values were resulted with 75% of recommended fertilizers and 2 t ha^{-1} oilcake (T_9) treatment and the lowest concentrations were recorded with the control (Appendices 4.14, 4.15, 4.16 and 4.17).

4.3.4. Nutrient Concentration in Lentil

The N, P, K, S and Zn concentrations in grain and stover of lentil were significantly influenced by the application of different treatments in two years of experiments. The N, P, K, S, Zn and B concentrations in grain of lentil varied from 3.05 to 4.92%, 0.17 to 0.42%, 0.33 to 0.45%, 0.07 to 0.15%, 32.18 to 53.70 µg g^{-1} and 0.87 to 2.06 µg g^{-1}due to application of different treatments. The highest N, P, S and B concentrations in grain were recorded with T_9 (75% of recommended fertilizers and 2 t ha^{-1} oilcake) treatment. But the highest concentrations of K and Zn in lentil grain were observed with T_7(75% of recommended fertilizers + 5 t ha^{-1} cow dung) and T_6(recommended fertilizers)treatments, respectively. The highest concentrations of N, P, K, S, Zn and B were 1.24%, 0.091%, 0.74%, 0.10%, 28.48 µg g^{-1} and 10.74 µg g^{-1}, respectively. The highest N and K concentrations in lentil stover were found with T_2(chemical fertilizers N, P, K and Zn applied by farmers + recommended S & B) treatment and P concentration was recorded with T_4 treatment. The maximum S, Zn and B concentrations in lentil stover were observed with T_9 treatment. The lowest nutrient concentrations in grain and stover of lentil were noted with the control treatment receiving neither fertilizer nor manure (Appendices 4.18, 4.19, 4.20 and 4.21).

The results indicated that the application of cow dung, poultry manure and oilcake along with chemical fertilizers resulted in considerable higher concentrations of nutrients than that of fertilizers applied by farmers or recommended fertilizers or soil test based treatments. The application of oilcake or poultry manure in combinationwith chemical fertilizers resulted in considerable higher concentrations of nutrients in mustard crops compared to fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers or control treatments. The combined application of chemical fertilizers and oilcake or poultry manure significantly increased the nutrient concentrations in grain and stover of lentil over other treatments.

4.4. Nutrient Uptake by Different Crops

The nutrient uptake by different crops (jute, rice, mustard and lentil) increased with the application of that particular nutrient. The nutrient uptake by different parts of jute, rice, mustard and lentil has been calculated from data of nutrient concentration and crop yield.

4.4.1. NutrientUptake by Jute

4.4.1.1. Nitrogen uptake by jute stick with bark

The uptake of N by jute stick with barkas influenced by applied treatments is shown inAppendices 4.8a and 4.8b. The uptake of N by jute plants was significantly affected due to application of different treatments in two soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns.

In Sara series, the N uptake by jute stick with barkvaried from 36.56 to 88.97 kg ha^{-1}in the first year and from 35.23 to 87.71 kg ha^{-1}in the second year. The highest N uptake (88.97 kg ha^{-1}) was recorded with T_5 (75% of farmers' practice + recommended S & B + 2 t ha^{-1}oilcake) treatment which was statistically similar to T_6, T_7 and T_9 treatments during two years of experiments. The lowest N uptake (35.23 kg ha^{-1}) was observed with T_0 (control) treatment in both years. The highest N uptake value was 143.35% higher compared to the control. The second highest N uptake by jute stick with barkof 87.10 kg ha^{-1} produced with T_7 (75% of recommended fertilizers + 5 t ha^{-1} cow dung) treatment which was significantly higher compared to T_0 (control) treatment (Figure 4.34 and Appendix 4.8a).

In Gopalpur series, the highest N uptake of 71.63 kg ha^{-1}by jute stick was recorded with T_9treatment and the lowest N uptake of32.67 kg ha^{-1} was found with T_0 (control) treatment in two years of field experiments. The N uptake increased in the second year with chemical fertilizers and organic manures treated plots compared to the first year (Figure 4.36 and Appendix 4.8b). The highest N uptake value was about 113.19% higher over control. The effect of T_9 treatment was statistically similar to T_1 (farmers' practice) and T_5(75% of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake) treatment but superior to the rest of the treatment.

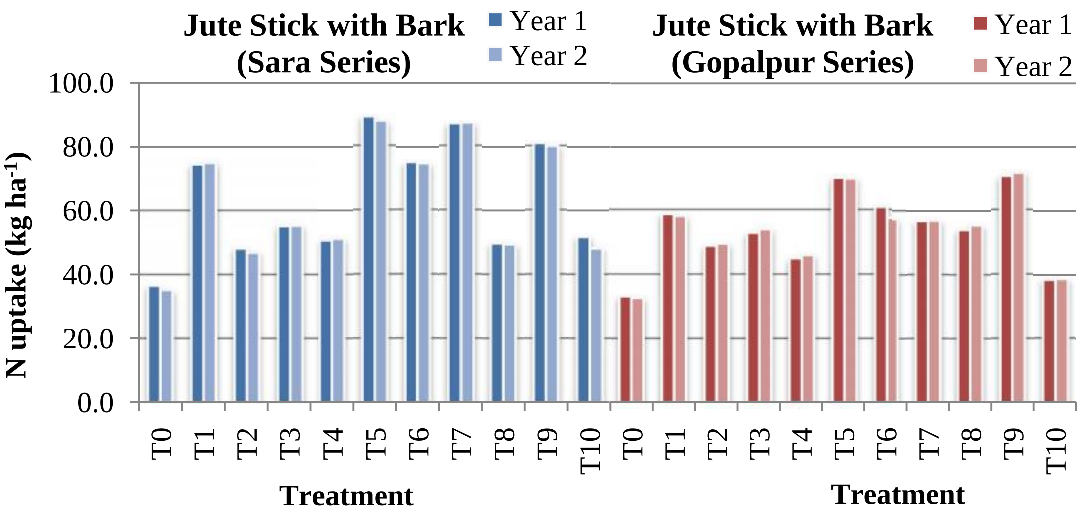

Figure 4.34. Nitrogen uptake by jute stick with barkof Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Data presented in Figure 4.34 show that the uptake of N by jute stick with barkwas higher in plots treated combinedly with chemical fertilizers and organic manures compared to the chemical fertilizer alone. The results of both soilsindicated that the application of chemical fertilizers + oilcake (T_5) treatment remitted in significant changes in N content and uptake by jute stick compared to all other treatments. The effect of chemical fertilizers + oilcake was statistically similar to chemical fertilizers + cow dung treatment but superior to the rest of the treatments including chemical fertilizers + poultry manure treatment. Stark *et al.* (1983) reported that total N uptake was related to N application, but was less when the supply of N exceeds 300 kg ha^{-1}. N uptake by jute stick with bark increased with increasing N fertilizers (Alam *et al.*, 1991).

4.4.1.2. Phosphorus uptake by jute stick with bark

The application of different treatments at different combinations causedsignificant changes in P uptake by jute stick with barkin both soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns (Appendices 4.8a and 4.8b).

In Sara series, the P uptake by jute stick with barkvaried between 7.12 and 17.39 kg ha^{-1}in the first year and between 6.68 and 17.96 kg ha^{-1}in the second year (Figure 4.35 and Appendix 4.8a). The highest total P uptake was in general found with T_5(75% of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake) treatment which was statistically dissimilar to all other treatments except T_3 treatment and lowest value was observed with T_0 (control) treatment in both years.The highest P uptake was 168.86% higher over control. The P uptake in jute stick was higher in the second year than that of the first year in almost all treatments except T_0 and T_{10} treatments. The magnitude of P uptake by jute stick with barkdue to application of different treatments followed the decreasing order of $T_0 < T_1 < T_{10} < T_9 < T_2 < T_4 < T_6 < T_8 < T_7 < T_3 < T_5$.

In Gopalpur series, the highest P uptake by jute stick with barkof 25.56 kg $ha^{-1}$was observed with T_4 treatment (75% of farmers' practice + recommended S & B + 3 t ha^{-1} poultry manure), which was statistically superior to all other treatmentsexcept T_8 treatment and the lowest value of 6.89 kg ha^{-1}P uptake with control treatment in the first year. The P uptake varied from 6.32 kg $ha^{-1}$with T_0 treatment to 20.84 kg $ha^{-1}$with T_4 treatmentin the second year (Figure 4.35 and Appendix 4.8b). The magnitude of P uptake by jute stick with barkdue to application of different treatments followed the decreasing order of $T_0 < T_1 < T_6 < T_2 < T_{10} < T_5 < T_7 < T_9 < T_3 < T_8 < T_4$.

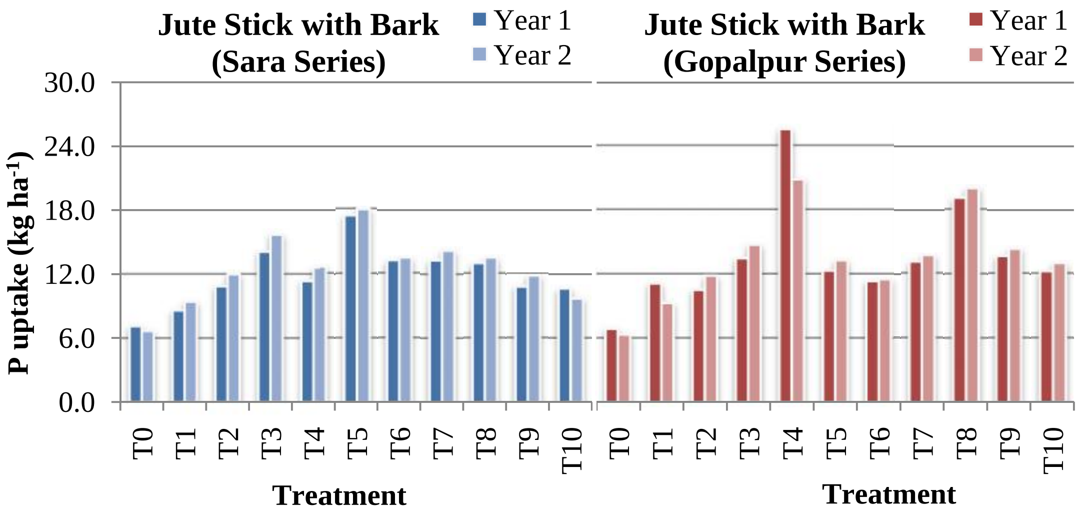

Figure 4.35. Phosphorus uptake by jute stick with barkof Sara and Gopalpur series as influenced by different treatments during two years of experiments.

All the treatments showed significantly higher P uptake by jute stick with barkover control (Figure 4.35). These results indicated that the P uptake by jute stick with bark was higher in chemical fertilizer and organic manures treated soils than that of only chemical fertilizer. The data showed that the effectof chemical fertilizers + oilcake treatment was statistically identical to chemical fertilizers + cow dung treatment in Sara series, but in case of Gopalpur series the effect of chemical fertilizers +poultry manure treatment was statistically different from the chemical fertilizers + and chemical fertilizers + cow dung treatments.Besford (1979) reported that high levels of nitrogen increased the uptake of P when an adequate level of this nutrient was supplied. The range of P removal was between 7.81 and 28.22 kg P ha^{-1} depending on the varieties used, fertilizer and location, reported by Alam *et al.* (1991).

4.4.1.3. Potassium uptake by jute stick with bark

Potassium uptake by jute stick with barkfrom two different soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns are presented in Appendices 4.8a and 4.8b. The uptake of potassium by jute stick indicated significant variations among different treatments.

In Sara series, the highest K uptake (171.27 kg ha^{-1}) was recorded with T_7 (75% of recommended fertilizers + 5 t ha^{-1} cow dung) treatment and the lowest (63.65 kg ha^{-1}) was measured with control in the first year. The K uptake varied from 56.45 kg ha^{-1} with T_0 treatment to 138.17 kg ha^{-1} with T_7 treatment in the second year. The effect of T_7treatment was statistically identical to T_2, T_3, T_4, T_5 and T_9 treatments but dissimilar to rest of the treatments (Figure4.36 andAppendix 4.8a).

In Gopalpur series, uptake of potassium by jute stick with barkvaried from 62.07 kg ha^{-1} to 149.22 kg ha^{-1}in the first year and from 60.00 to 160.54 kg ha^{-1}in the second year under different treatments. The highest potassium uptake was found with T_8 treatment during two years of experiments which was statistically superior to all other treatments. The lowest K uptake was observed in the control plot in both years (Figure4.36 andAppendix 4.8b). The results indicated that K uptake by jute stick was betterwith chemical fertilizers and organic manures treated plots compared to other treatments.

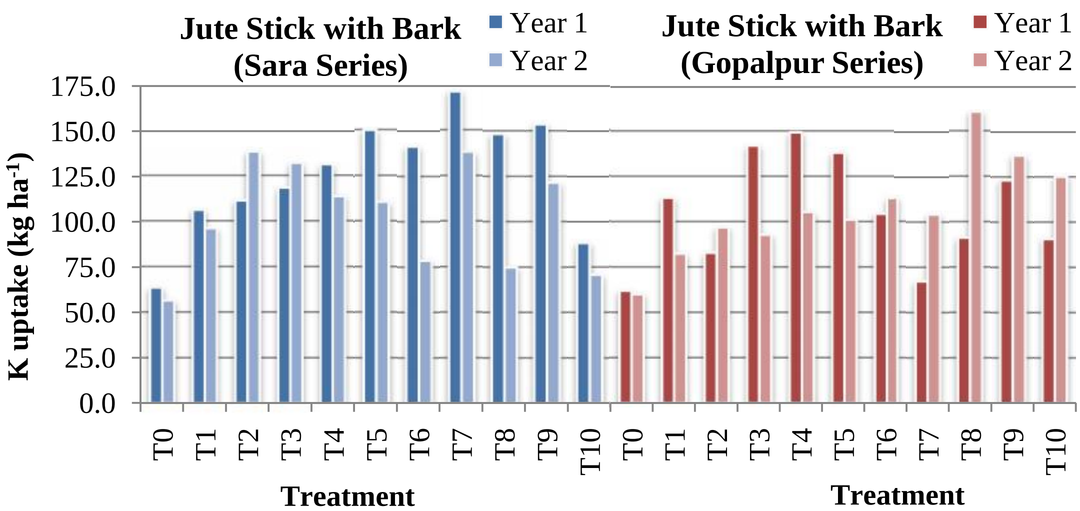

Figure 4.36. Potassium uptake by jute stick with barkof Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.36 shows that the potassium uptake by jute stick with barkwas higher under the combined application of chemical fertilizers and organic manures (cow dung, poultry manure and oilcake) than that of chemical fertilizer alone. The results of organic manure based treatments gives an indication that the K uptake by jute stick and bark with chemical fertilizers + poultry manure treatment was statistically superior to the chemical fertilizers + oilcake and chemical fertilizers + cow dung treatments.Mazumdar *et al.* (2014) reported that the highest potassium uptake with 150% NPK, followed by 100 % NPK+FYM and the lowest K uptake in the control plot in different parts of jute. Messey and Winsor (1980) observed that total uptake of K increased with the increment of N supply. Sarkar *et al.* (2000) also found increased uptake of K with increased potassium supply. Alam *et al.* (1994) and Mandal (1970) also found the similar trend of results.

4.4.1.4. Sulphur uptake by jute stick with bark

The uptake of S by stick with barkof jute grown in two soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns was significantly influenced by different treatments (Appendices 4.9a and 4.9b).

In case of jute stick of Sara series, the highest uptake was recorded with the T_7treatment (75% of recommended fertilizers + 5 t ha^{-1} cow dung) which increased the S uptake by 186.94% over the control. In the first year, the S uptake by jute stick with bark ranged from 7.13 to 18.39 kg ha^{-1} and in the second year, the values were varied from 6.89 to 19.77 kg ha^{-1} under different treatments. The effect of T_7 treatment was statistically similar to T_5 (75% farmers' practice + 75% recommended S&B + 2 t ha^{-1}oilcake), T_8(75% of recommended fertilizers + 3 t ha^{-1} poultry manure) and T_9(75% recommended fertilizers + 2 t ha^{-1} oilcake) but superior to rest of the treatments(Figure 4.37 and Appendix 4.9a). The results of S uptake by jute stick obtained from the application of different treatments can be ranked in the order of $T_7> T_8> T_9> T_5> T_6> T_3> T_2> T_{10}> T_1> T_4> T_0$.

In the jute stick with barkof Gopalpur series, the S uptake ranged from the lowest value of 7.24 kg ha^{-1} with T_0 (control) treatment to 14.90 kg $ha^{-1}$with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment which was 105.80% higher over controlin the first year. In the second year, the S uptake varied between 6.86 with control and 13.78 kg ha^{-1} with T_8 treatment which was 100.87% higher over the control (Figure 4.37 and Appendix 4.9b). The results showed that the effect of T_8 treatmenton S uptake was statistically identical to T_4, T_5, T_7 and T_9 treatments but superior to the effects resulted from all other treatments. The S uptake by jute stick with bark obtained from different treatments can be ranked in the order of $T_8> T_9> T_4> T_5> T_{10}> T_7> T_1> T_6> T_3>T_2>T_0$.

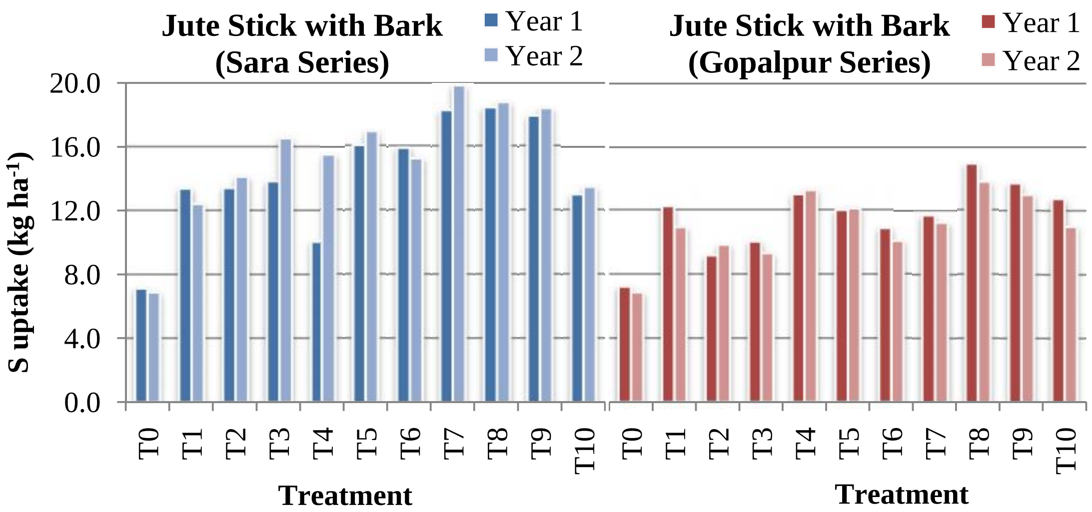

Figure4.37. Sulphuruptake by jute stick with barkof Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.37shows that the S uptake was highest due to the combined application of chemical fertilizer + cow dung in Sara series and chemical fertilizer + poultry manure in Gopalpur series over the application of chemical fertilizer alone or in combination with rest of the organic manures or control. The higher S uptake obtained with the application of organic manures especially cow dung and poultry manure might be in harmony with supply of nutrients at a rate sufficient to support growth. Alam *et al.* (1994) reported that the uptake of S by different parts of jute ranged from 2.05 to 3.23 kg ha^{-1} in root, 3.99 to 9.27 kg ha^{-1} in bark, 9.86 to 17.09 kg ha^{-1} in stem and 4.06 to 5.81 kg ha^{-1} in leaves.

4.4.1.5. Zinc uptake by jute stick with bark

The Zn uptake by jute stick with barkwas significantly influenced by different treatments applied through chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns (Appendices 4.9a and 4.9b).

In Sara series, the mean Zn uptake by jute stick with barkunder Jute - T. aman - Mustard cropping patternas affected by different treatments are presented in Appendix 4.9a. The highest Zn uptake by jute stick with barkof 222.45 g ha^{-1} was obtained with T_7(75% of recommended fertilizers + 5 t ha^{-1} cow dung)treatment and the lowest Zn uptake of 101.39 g ha^{-1} was found with T_0(control) treatment in the first year. The Zn uptake ranged between 94.09 g ha^{-1} with T_0 treatment and 262.61 g ha^{-1} with T_{10} treatment in the second year (Figure 4.38 and Appendix 4.9a). The effect of chemical fertilizers +cow dung(T_7) treatment on Zn uptake was statistically similar to all other treatments except

T_0 treatment. The levels of Zn uptake by jute stick with barkincreased in the second year compared to the values obtained in the first year with almost all treatments except T_0 and T_7 treatments. The enhancement varied from 37.62 to 179.79% combinedly in both years.

In Gopalpur series, the Zn uptake by jute stick with barkduring two years of experiments as influenced by different treatments are given in Appendix 4.9b. The uptake of zinc by jute stick in the first and second years varied from 78.58 to 202.35 g ha^{-1} and 77.94 to 213.81 g ha^{-1}, respectively. The highest Zn uptake was found with T_4 treatment receiving 75% of recommended fertilizers + 3 t ha^{-1} poultry manure, which was 155.70% higher than control, followed by T_8 treatment (185.28and 199.90 g ha^{-1}) receiving 75% of farmers' practice + recommended S & B + 3 t ha^{-1} poultry manure and the lowest Zn uptake (77.94 g ha^{-1}) was observed with the control plot in two years of experiment (Figure 4.38 and Appendix 4.9b). Therefore, the T_4 treatment showed a better effect on Zn uptake compared to other treatments and was statistically identical to all other treatments except T_0, T_1 and T_5 treatments.

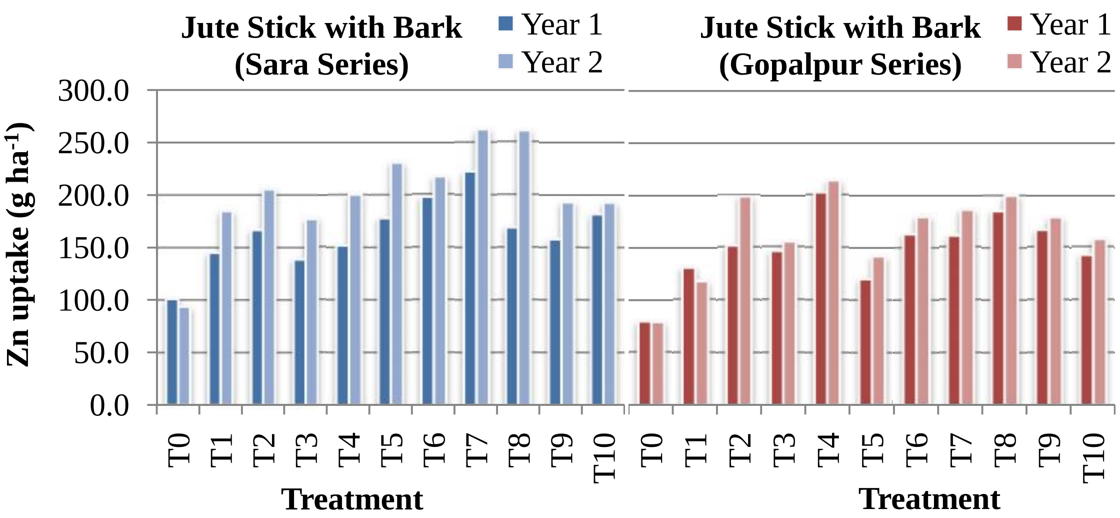

Figure 4.38. Zinc uptake by jute stick with barkof Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Data presented in Figure 4.38 show that the Zn uptake was increased in the second year compared to first year in all the treatments except T_0(control), T_1(chemical fertilizers applied by farmers) and T_7(75% of recommended fertilizers + 5 t ha^{-1} cow dung) treatments under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns. The results showed that the higher Zn uptake was found with the treatments comprised of chemical fertilizers and organic manures specially cow dung and poultry manure than that of chemical fertilizer alone. This was happened due to higher availability of Zn in soil reservoir besides the additional quantity of Zn supplied by organic manure.

4.4.1.6. Boron uptake by jute stick with bark

The data in Appendices 4.9a and 4.9b show a large variation in B uptake by jute stick from year to year and from treatment to treatment under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns.

In Sara series, the mean B uptake by jute stick with barkunder Jute - T. aman - Mustard cropping system with different treatments are presented in Appendix 4.9a. Plots amended with 75% of recommended fertilizers + 3 t ha^{-1} poultry manure (T_8) treatment produced highestvalue of 322.42 g ha^{-1} B uptake and the lowest value of 109.63 g ha^{-1} was found with control plots in the first year. The B uptake by jute stick ranged between 104.10 g ha^{-1} with T_0 treatment and 388.16 g ha^{-1} with T_8 treatment in the second year (Figure 4.39 and Appendix 4.9a). The effect of T_8 treatment on B uptakewasstatistically identical to T_3, T_4, T_5, T_7 and T_9 treatments but superior to rest of the treatments. The levels of B uptake by jute stick with barkimproved inalmost all plots amended with different treatments except T_0, T_6 and T_{10} treatments in the second year compared to the first year. The improvements varied from 24.04 to 273.08% in both years. With respect to average boron uptake by jute stick during two years, the treatments can be arranged in the following order:$T_8 > T_4 > T_9 > T_7 > T_3 > T_5 > T_2 > T_6 > T_1 > T_{10} > T_0$(Figure 4.41).

In Gopalpur series, the B uptake by jute stick with barkduring two years of experiments as influenced by various treatments is given in Appendix4.9a. The uptake of boron by jute stickin the first and second yearsvaried from 102.53 to 302.79 g ha^{-1} and 100.10 to 319.35 g ha^{-1}, respectively under different treatments (Figure 4.39 and Appendix 4.9b). The highest B uptake was found with T_4 treatment receiving 75% of recommended fertilizers + 3 t ha^{-1} poultry manure, which was statistically identical to all other treatments except T_0(control) and T_1 (farmers' practice) treatments.The lowest B uptake was observed with the control treatment in both years. The uptake of average boron of two years obtained from different treatments can be ranked in the following order:$T_4 > T_8 > T_3 > T_7 > T_6 > T_9 > T_2 > T_{10} > T_5 > T_1 > T_0$ (Figure4.39). Therefore, chemical fertilizers and poultry manure (T_4) treatment showed a better effect on boron uptake over other treatments in two years of experiments.

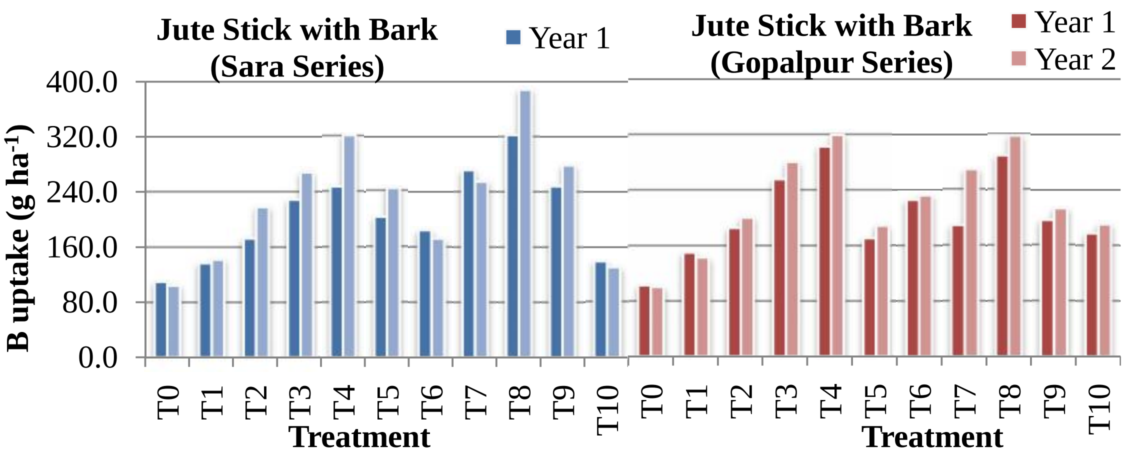

Figure 4.39. Boron uptake by jute stick with barkof Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Figure4.39 revealed that the combined application of chemical fertilizer and poultry manure played major role to increase the B uptake by jute stick over other manures and/or chemical fertilizers in two soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns. The effect of chemical fertilizer + poultry manure treatment was statistically higher compared to the other treatments. The results showed that there was an increase in B uptake by jute stick with a few exceptions of T_0 and T_6 treatments in the second year compared to the first year for two soils.The reason for increased uptake of B by jute stick over control was probably due to the residual effect of decomposable manures.

4.4.2. NutrientsUptake by Rice

The nutrient uptake by grain and straw of T.aman rice varied due to the application of different treatment combinations. The nutrient uptake by rice grain and straw was calculated from the data of nutrient concentration and their yields.

4.4.2.1. Nutrient Uptake by Rice Grain

4.4.2.1.1. Nitrogen uptake by rice grain

Significant effectson N uptake by BRRI Dhan39 rice due to use of various treatments applied through chemical fertilizers and organic manures (cow dung, poultry manure and oilcake) in two soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patternswere found (Appendices 4.10a and 4.10b).

In Sara series, the range of N uptake by rice grain was 18.96 to 52.52 kgha^{-1}in the first year (Appendix 4.10a and Figure 4.40). The highest N uptake (52.52kg ha^{-1}) by rice grain was found with T_6 treatment. The next highest N uptake was obtained with T_5(75%

of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake) treatment, which was statistically similar to other treatments except the control. The lowest N uptake (18.96 kgha^{-1}) by grain was found with T_0 (control)treatment. Similarly, the range of N uptake by grain was 18.96 to 60.64 kgha^{-1}in the second year (Appendix 4.10a and Figure 4.40). The highest N uptake by grainwas, however, obtained with T_9 treatment, which was statistically identical to the other treatments except T_0 treatment. The lowest N uptake (18.96 kg ha^{-1}) by grain was found with T_0 treatment.

In Gopalpur series, the highest (48.59kg ha^{-1}) N uptake by rice grain was observed with the T_2 treatment (chemical fertilizers applied by farmers + recommended S & B) and the lowest (20.17 kg ha^{-1}) N uptake was noted with T_0(control) treatmentin the first year(Appendix 4.10b and Figure 4.40).In the second year, the treatment T_5(75% of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake) showed themaximum (67.18 kg ha^{-1}) uptake of N and T_0treatment showed minimum uptake (19.57 kg ha^{-1}) of N by rice grain (Appendix 4.10b and Figure 4.42). The effect of chemical fertilizers + oilcake (T_5) treatment was statistically similar to all the treatments except T_0 (control) and T_6 (recommended fertilizers) treatments.

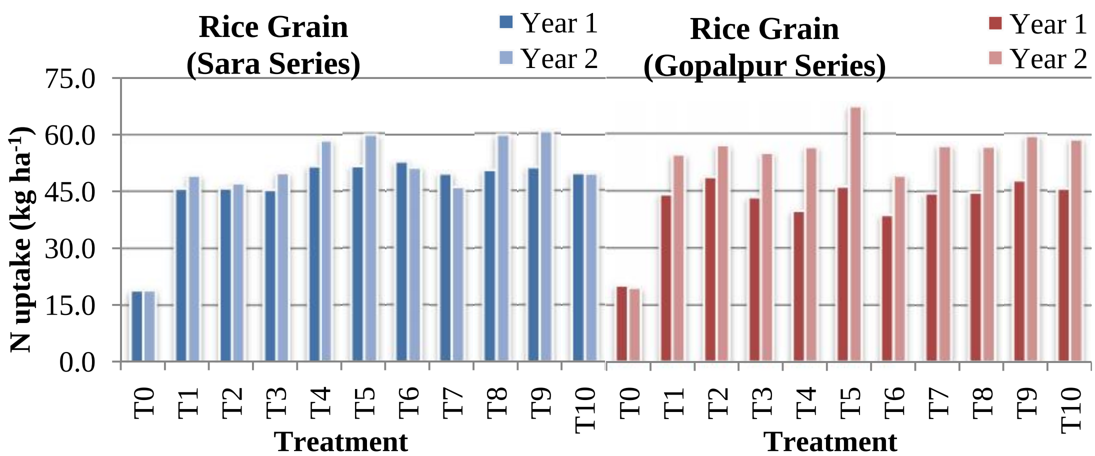

Figure 4.40. Nitrogen uptake by rice grain of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

The above Figure 4.40indicated that the oilcake had positive impact on enhancing N uptake by rice grain. The N uptake increased in the second year compared to the first year in both soils except control. The results indicated that the chemical fertilizers + oilcake treatment showed highest N uptake by rice grain among the three organic manures based treatments. Roul and Sarawagi (2005) found higher N uptake by rice under combined application of chemical fertilizer and manure.The findings of Jokela and

Randall (1989), Saleque *et al.* (2005),Hasan *et al.* (2009) and Islam *et al.* (2014) also corroborated with the observation of this study.

4.4.2.1.2. Phosphorus uptake by rice grain

The results presented in Appendices4.10a and 4.10b showed that P uptake byrice grain differed significantly due to application of different treatments in two soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns.

In Sara series, the range of P uptake by rice grain varied from 2.13to 8.57 kgha^{-1}in the first year and from 2.11 to 7.50 kg ha^{-1}in the second year of experiment. In the first year, the highest P uptake (8.57 kg ha^{-1}) by grain was recorded with T_8 treatment receiving 75% of recommended fertilizers + 3 t ha^{-1} recommended poultry manure and the lowest value (2.13kg ha^{-1}) of P uptake was recorded with T_0 (control). In the second year, the lowest value (2.11 kg ha^{-1}) of P uptake was rerecorded with control treatment and the highest (7.50 kg ha^{-1}) P uptake was observed with T_8 treatment, which was statistically identical to treatments T_3, T_5, T_7 and T_9 but superior to rest of the treatments (Appendix 4.10a and Figure 4.41).

In Gopalpur series, the P uptake by rice grain was significantly affected by different treatments. In the first year, the highest P uptake (12.41 kg ha^{-1}) by rice grain was observed with T_5 treatment (75% of farmers' practice + 75% recommended S & B + 2 t ha^{-1} recommended oilcake), which was statistically similar to all other treatments except T_0 treatment. The lowest P uptake (4.25 kg ha^{-1}) by rice grain was observed in control treatment. In the second year, phosphorus uptake by rice grain varied from 4.04 kg ha^{-1} with T_0 treatment to 11.66 kg ha^{-1} with T_5 treatment (Appendix 4.10b and Figure 4.41).

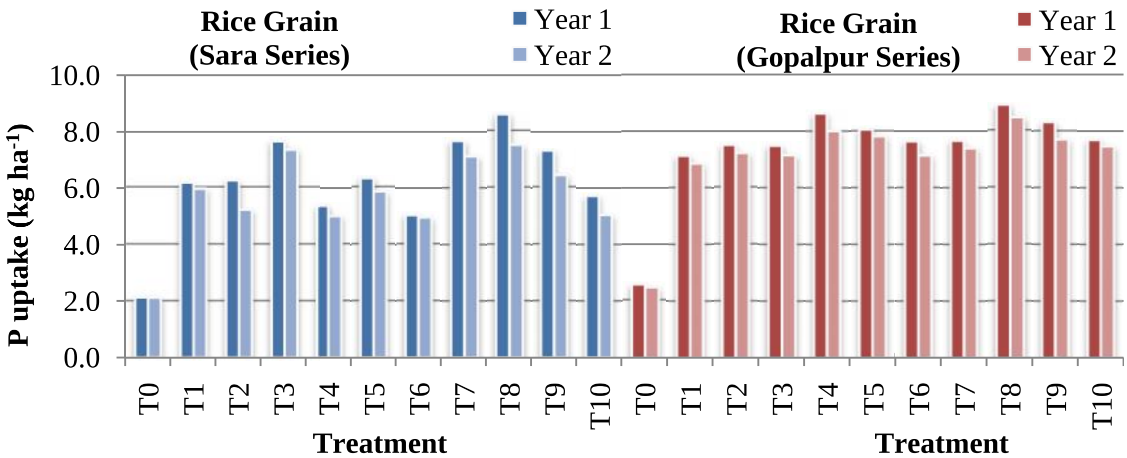

Figure 4.41. Phosphorus uptake by rice grain of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.41 shows that the P uptake wasreduced in the second year compared to first year in all the treatments used in soils under both cropping patterns. The highest P uptake was found with the treatments comprised of chemical fertilizers and poultry manure in both soil series, which was statistically similar to chemical fertilizers + cow dung treatment in Sara series and similar to other treatments except control in Gopalpur series. This was happened due to higher content of P in organic manure.Hasan *et al.* (2009) reported that the P content in grain and straw were increased with the combined application of N, P, K, S and Zn. The application of organic sources of nutrient significantly increased the uptake of NPK by rice grain (Ritamoni *et al.*1999). These results supported the findings of Sengar *et al.* (2000) andBhuiyan *et al.* (2011) who reported that cow dung along with chemical fertilizers resulted in markedly higher uptake of P.

4.4.2.1.3. Potassium uptake by rice grain

There was a significant effect of different treatments applied through chemical fertilizers and organic manure on potassium uptake by grain of T. aman rice cultivated in soils of Sara series (Appendix 4.10a) and was non-significantly influenced in soils of Gopalpur series (Appendix 4.10b).

In Sara series, theresults indicated that the K uptake by grain of T. amanrice were significantly affected by different treatments. The highest K uptake (11.05 kg ha^{-1}) of grain was observed with T_8 treatment (75% of recommended fertilizers + 3 t ha^{-1} recommended poultry manure), which was statistically similar to all other treatments except T0 (control) and T6 (recommended fertilizers) treatments. The lowest K uptake of grain was recorded with T_0 treatment. In the second year,the lowest total K uptake (3.01 kg ha^{-1}) was observed with T_0 treatment and the highest K uptake (11.96 kg ha^{-1}) by rice grain was recorded withT_8 treatment (Appendix 4.10a and Figure 4.42).

In Gopalpur series, the results indicated that K uptake by T. aman rice grain were non-significantly affected by different treatments (Appendix 4.10b). In the first year, the K uptake by rice grain ranged between 3.11 kg ha^{-1} with T_0 treatment and 10.63kg $ha^{-1}$with T_8 treatmentin the first year(Appendix 4.10b and Figure 4.42). In the second year, the highest K uptake (10.90 kg ha^{-1}) by grainwas also observed with T_8 treatment, which was statisticallyidentical to all other treatments except T_0 treatment.

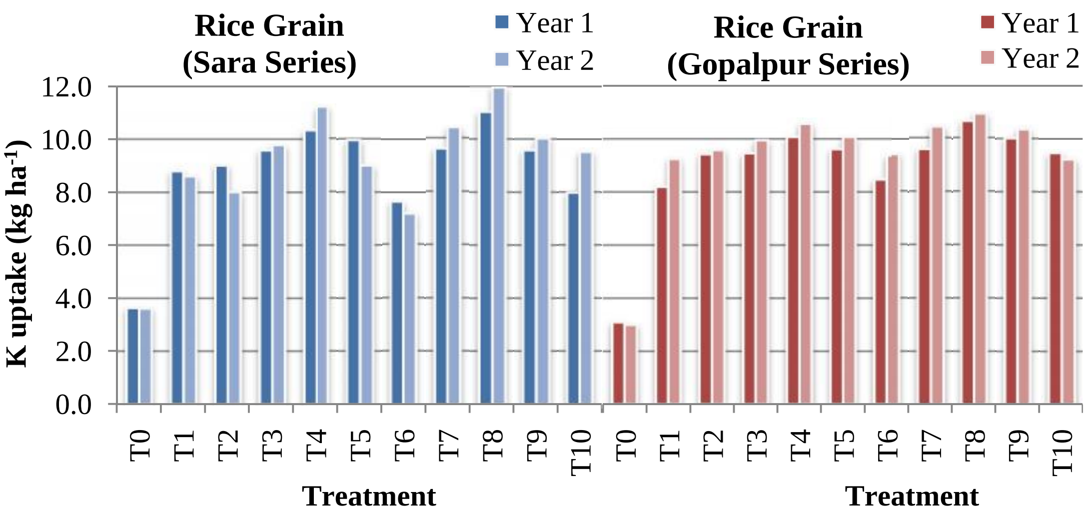

Figure 4.42. Potassium uptake by rice grain of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.42 shows that the synthetic fertilizer treatments yielded reduced trend of K uptake, where the combined application of chemical fertilizers and organic manure provided increasing trend of K uptake. The results indicated that the application of chemical fertilizer in combination with organic manure showed the higher K uptake than that of the chemical fertilizer alone. Jagadeeswari *et al.* (2001) reported that potassium uptake by rice grain increased due to the application of cow dung along with NPK fertilizers.

4.4.2.1.4. Sulphur uptake by rice grain

The data presented in Appendices 4.11a and 4.11b indicated that S uptake by grain of T. aman rice was influenced significantly due to the application of different treatments in two soils under two cropping patterns.

In Sara series, the S uptake by rice grain ranged from 0.92 to 3.84 kgha^{-1}in the first year (Figure 4.43 and Appendix 4.11a). The highest S uptake of 3.84 kg ha^{-1}by rice grain was found with T_4 treatment (75% of farmers' practice + 75% recommended S & B + 3 t ha^{-1} poultry manure) and the lowest S uptake of 0.92 kg ha^{-1}was recorded with control treatment. In the second year, the S uptake by rice grain varied from 0.90with control to 4.05 kg ha^{-1}with T_9 (75% of recommended fertilizers + 2 t ha^{-1} oilcake) treatment (Figure 4.43 and Appendix4.11a). The highestquantity of S uptake by rice grain wasrecorded with chemical fertilizers+ oilcake(T_9) treatment, which was statistically identical to other treatments except T_0, $T_1$and T_3treatments. The lowest S uptake by grain was found with T_0(control) treatment.

In Gopalpur series, the S uptake of rice grain ranged from 1.01 to 3.45 kgha^{-1}in the first year and from 0.97 to 4.26 kg ha^{-1}in the second year (Figure 4.43 and Appendix4.1b). In the first year, the highest S uptake by grain was found with T_5 treatmentreceiving 75% of recommended fertilizers + 2 t ha^{-1} oilcakeand the lowest S uptake (1.01 kg ha^{-1}) by rice grain was found with T_0 treatment. In the second year, the lowest S uptake of 0.97 kg ha^{-1}was found with T_0 (control) treatment and the highest quantity of S uptake of 4.26 kg ha^{-1}by grain was recorded with T_2(chemical fertilizers applied by farmers + recommended S & B) treatment.

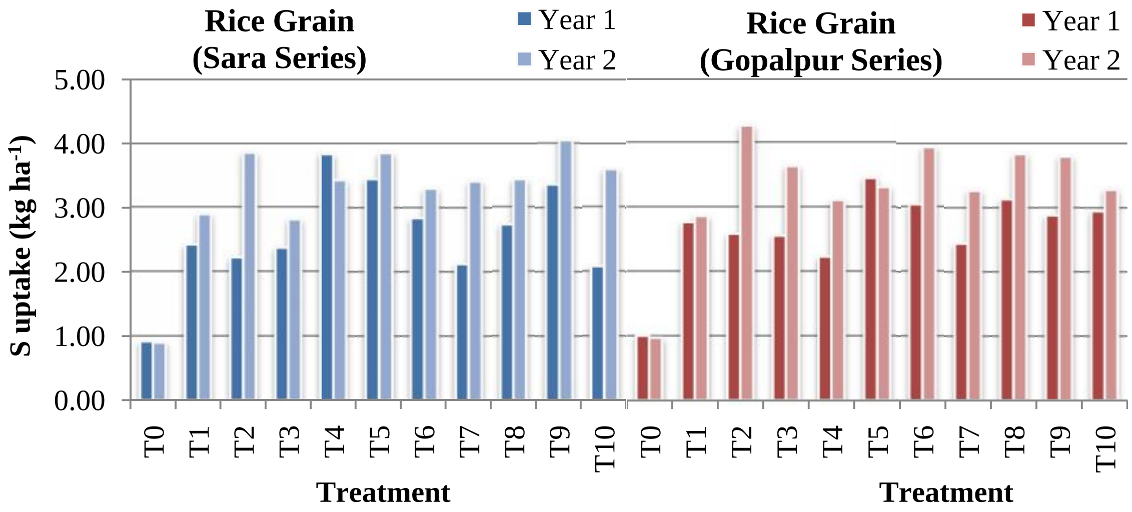

Figure 4.43. Sulphur uptake by rice grain of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.43 clearly shows that the S uptake by grain in the second year was higher than that of first year with almost all treatments except T_0 and T_4 treatments in Sara series and T_0 and T_5 treatments in Gopalpur series. The S uptake by rice grain in both soils did not show any trend in its change. The results of two soil series indicated that the addition of organic manures had no remarkable influence on S uptake by rice grain. Bhuiyan*et al.* (2011) reported that the application of cow dung along with chemical fertilizers resulted in markedly higher uptake of S by rice. The results observed in this experiment were also supported by the findings of Rashid (2009).

4.4.2.1.5. Zinc uptake by rice grain

Anon-significant effect of different treatments applied through chemical fertilizers alone or in combination with organic manure on zinc uptake by the grain of T. aman rice cultivated in two soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns was observed (Appendices 4.11a and 4.11b).

In Sara series, there was a variation in Zn uptake by T. aman rice due to various treatments (Appendix 4.11a). In both years, the highest Zn uptake was recorded with T_9 treatment and the lowest Zn uptake was found with the control treatment (Figure 4.44 and Appendix 4.11a). The effect of recommended chemical fertilizers + oilcake on Zn uptake by rice grain was statistically similar to all other treatments except T_0 (control) treatment.

In Gopalpur series, data pertaining to the effects of organics and inorganics on Zn uptake by rice grain are presented in Appendix 4.11b which revealed that there were non-significant variations during both the years of experiment (Figure 4.44 and Appendix 4.11b). The effect of recommended chemical fertilizers + oilcake on Zn uptake by rice grain was also statistically similar to all other treatments except T_0 (control) treatment.

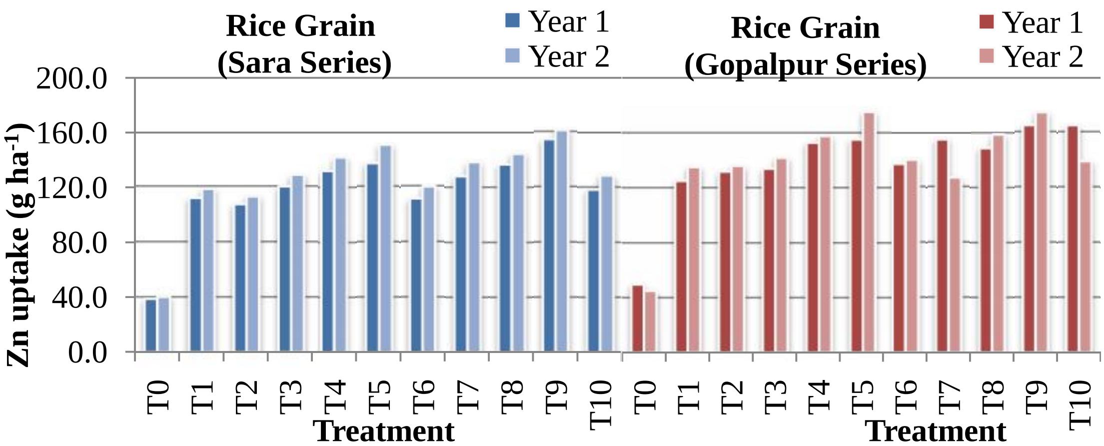

Figure 4.44. Zinc uptake by rice grain of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

The data show that Zn uptake by rice grain increased in the second yearwith almost all the treatments except T_0 and T_7 treatments in Gopalpur series than that of first year (Figure 4.44). The Zn uptake by rice grain was statistically higher with the combined application of chemical fertilizer and oilcake (T_9) treatment compared to the other treatments in both soils. The application of chemical fertilizers and organic manures proved to increase the Zn uptake by rice grain as against the application of fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers or control treatments. Application of organic manures increased the Zn uptake which might be due to greater availability of micronutrients present in the soil as well as in the organics. Duhan and Singh (2002) reported the increased Zn uptake due to application of fertilizer nitrogen. Brohi *et al.* (2000) reported that the application of chemical fertilizer (Mg and

K fertilization) had a significant effect on the Zn contents and uptake by grain and straw and was increased with K and Mg treatment.

4.4.2.1.6. Boron uptake by rice grain

The effect of different treatments was significant on boron uptake in grain of T. aman rice (Appendices 4.11a and 4.11b). The results showed that the use of chemical fertilizers individually or in combination with cow dung, poultry manure and oilcake produced different results of B uptake under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns.

In Sara series, the B uptake by grain was significantly influenced due to different treatments (Appendix 4.11a). The B uptake by grain varied from 1.59 to 7.69 gha^{-1}in the first year and 1.61 to 8.34 gha^{-1}in the second yearof experiments. It was observed that the B uptake was always maximum with T_8 treatment (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) and minimum with control (Figure 4.45 and Appendix 4.11a). In all the experiments, the B uptake by rice grain with T_8 treatment was statistically identical to T_4, T_5, T_6, T_9 and T_{10} treatments but superior to the rest of the treatments.

In Gopalpur series, the application of different treatments also influenced significantly the boron uptake by rice grain (Appendix 4.11b). In both years, the highest B uptake were observed with T_{10} (soil analysis based treatment) treatment which was statistically similar to all the treatments except T_0, T_5, T_7 and T_9 treatments and the lowest with control (T_0).

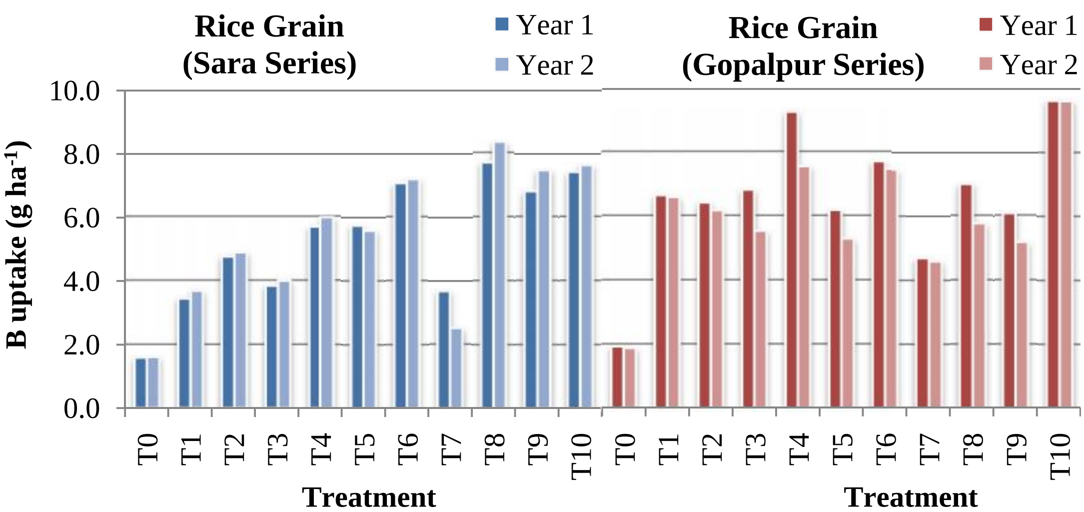

Figure 4.45. Boron uptake by rice grain of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Data presented in Figure 4.45 show that the B uptake was reduced in the second year compared to the first year with almost all the treatments under both cropping patterns. The higher value of B uptake was found with the treatments comprised of chemical fertilizer alone than that of chemical fertilizers and organic manures. The results indicated that the combined application of chemical fertilizers and organic manures had no considerable influence on the B uptake by rice grain.Contrary to the findings of this experimentBhuiyan*et al.* (2011) reported that the B uptake by T. aus remarkably increased with increasing supply of nutrients through cow dung along with chemical fertilizers.

4.4.2.2. Nutrients Uptake by Rice Straw

4.4.2.2.1. Nitrogen uptake by rice straw

The uptake of nitrogen by rice straw in two years of experiments underJute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns was significantly influenced due to the application of different treatments (Appendices 4.12a and 4.12b).

In Sara series, data on N uptake by rice straw at harvest are presented in Appendix 4.12a. The N uptake by rice strawranged from 17.76 to 48.40 kg ha^{-1}in the first year and from 17.47 to 49.19 kg ha^{-1}in the second year due to application of different treatments (Figure 4.46 and Appendix 4.12a). The highest N uptake was recorded with T_9treatment (75% of recommended fertilizers + 2 t ha^{-1} oilcake), which was statistically similar to T_4, T_8 and T_9 treatments but superior to rest of the treatments and the lowest value was found with T_0 treatment in both the years.

In Gopalpur series, the effect of different treatments on nitrogen uptake by straw of T. aman rice was significant (Appendix 4.12b). In the first year, the highest N uptake of 39.70 kg $ha^{-1}$by rice straw was observed with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment and the lowest N uptake of 13.62 kg ha^{-1} was found with T_0 treatment. In the second year, the N uptake byrice straw varied from 13.32 to 41.32 kg ha^{-1}, where the highest N uptakeby rice straw was also found with T_8 treatment and the lowest uptake was observed with T_0 treatment (Figure 4.46 and Appendix 4.12b). The effect of recommended fertilizers + poultry manure (T_8) treatment was statistically similar to other treatments except T_0, T_1, T_2 and T_{10} treatments.

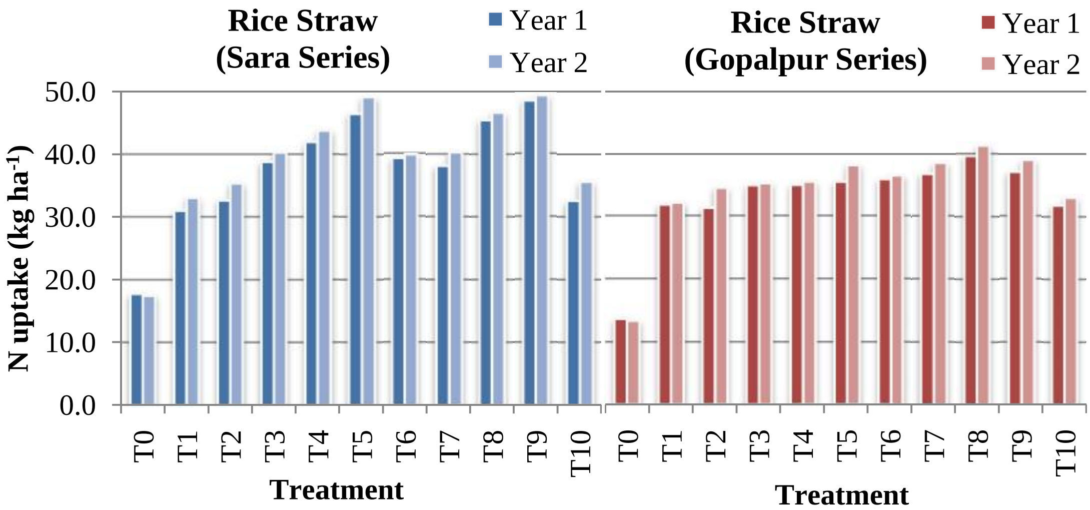

Figure 4.46. Nitrogen uptake by rice straw of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Data presented in Figure 4.46 show that the N uptake by rice straw was morein the second year than that of first year under two different cropping patternsexcept T_0 treatment of both soils. The N uptake by rice straw was statistically higher in chemical fertilizer + oilcake treatment (T_9) over other treatments in Sara series, on the other hand N uptake was higher in chemical fertilizers + poultry manure treated plots (T_8) in Gopalpur series than that of the others.The results indicated that the combined application of chemical fertilizers and organic manures may influence the N uptake in rice graincompared to other treatments. Zamil *et al.* (2004) found that the N uptake by rice straw was significantly influenced by organic manures and nitrogen fertilizer.

4.4.2.2.2. Phosphorus uptake by rice straw

The results presented in Appendices 4.16a and 4.12b indicated that the P uptake by straw of T. aman rice was influenced significantly due to the application of different treatments in two soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns.

In Sara series, the treatments effects were significant and thehighest P uptake (9.68 kg ha^{-1}) by rice straw was recorded with T_4 (75% of farmers' practice + 75% recommended S & B + 3 t ha^{-1} poultry manure) treatment and the lowest P uptake (3.23 kg ha^{-1}) was found with T_0 treatment, in the first year(Figure 4.47 and Appendix 4.12a). In the second year, the highest P uptakeof 9.90 kg ha^{-1} was observed with T_5 (75% of farmers' practice + 75% recommended S & B + 2 t ha^{-1} oilcake) treatment, which was statistically identical to the T_4, T_8 and T_9 treatments but superior to the rest of the treatments and the lowest uptake of 3.23 kg ha^{-1} was found with T_0 treatment (Figure 4.49 and Appendix 4.12a).

In Gopalpur series, the total uptake of P by rice straw ranged from 2.69 to 7.89 kgha^{-1} and from 2.63 to 8.36 kg ha^{-1}in the first year and second year, respectively (Figure 4.47 and Appendix 4.12b). The highest P uptake was observed with T_8(recommended fertilizers + poultry manure) treatment, which was statistically similar to T_4 and T_5 treatments but superior to the rest of the treatmentsand the lowest was also recorded with T_0 treatment in both years of experiments.

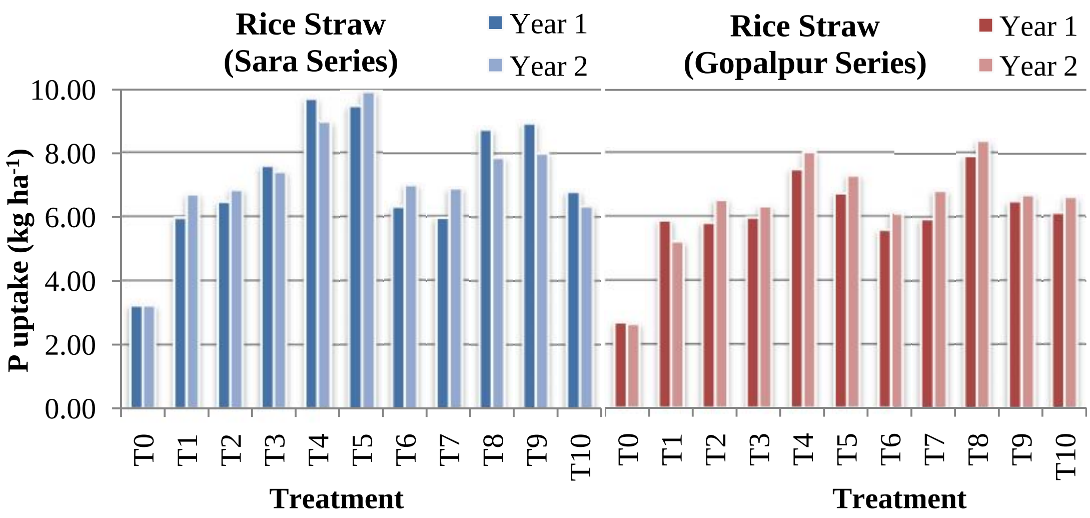

Figure 4.47. Phosphorus uptake by rice straw of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Total P uptake by T. aman rice straw showed wide variation with different treatments (Figure 4.47). The application of oilcake with chemical fertilizers in Sara series and poultry manure with chemical fertilizers resulted in considerably higher uptake of P by rice straw compared to other treatments in the respective soils. The results indicated that combined application of chemical fertilizers and organic manures produced more P uptake than that of chemical fertilizer treatments only.The data shows that the effectof chemical fertilizers + oilcake on P uptake was statistically identical to the chemical fertilizers + poultry manure treatment but superior to the rest of the treatments. All the three orMohanty*et al.* (2013) reported that P uptake by rice was the highest with the combined application of nitrogen fertilizer, farm yard manure and *Azolla*.

4.4.2.2.3. Potassium uptake by rice straw

Data on the K uptake by rice straw due to various treatments are presented in Appendices 4.12a and 4.12b which show significant variations for two different soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns during two years of experiment.

In Sara series, the K uptake by rice straw ranged from 43.80 to 157.60 kg ha^{-1} due to different treatments applied in the first year (Figure 4.48 and Appendix 4.12a). The highest K uptakewas recorded with T_5 (75% of farmers' practice + 75% recommended S & B + 2 t ha^{-1} oilcake) treatment which was statistically similar to other treatments except T_0 and T_6 treatments andthe lowest was found with T_0 treatment. In the second year, the K uptake by rice straw was lowest of 42.60 kg $ha^{-1}$with control treatment, which increased to the highest value of 196.30kg ha^{-1} due to the application of 75% of recommended fertilizers + 2 t ha^{-1} oilcake (T_9) treatment (Figure 4.48 and Appendix 4.12b).

In Gopalpur series, the K uptake by rice straw was significantly influenced by different treatments. The highest value of K uptake of 124.93kg ha^{-1} by rice straw was found with T_2 treatment receiving chemical fertilizers applied by farmers + recommended S & Band the lowest K uptake of 38.47kg ha^{-1} was recorded with T_0 treatment in the first year (Figure 4.48 and Appendix 4.12b). In the second year, the K uptake by rice straw varied from 37.30 to 155.00 kg ha^{-1} due to different treatments effects. The highest K uptake by straw was observed with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment, which was statistically identical to the chemical fertilizers + cow dung and chemical fertilizers + oilcake treatmentsand the lowest K uptake was noted with the control treatment (Figure 4.48 and Appendix 4.12b).

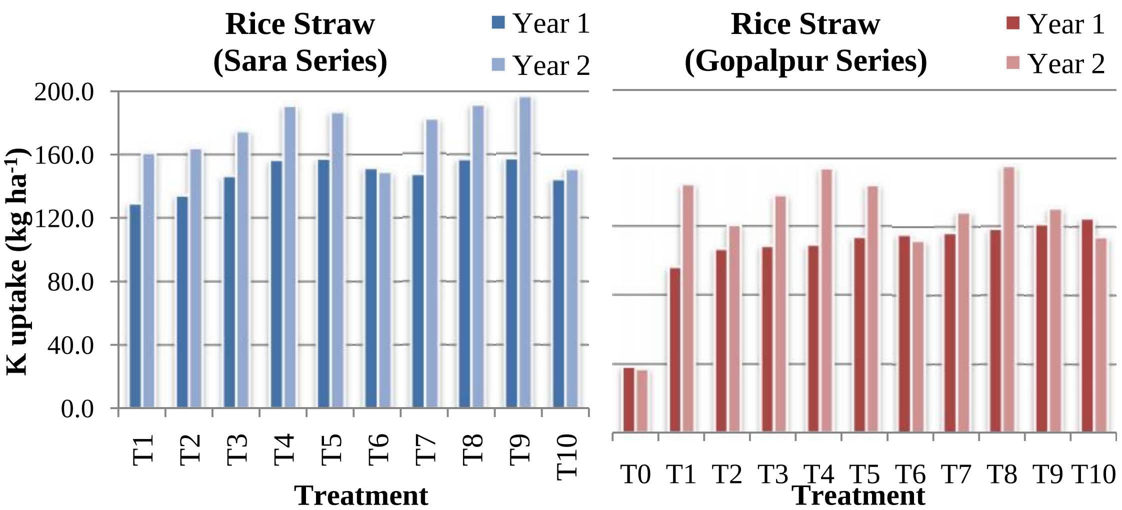

Figure 4.48. Potassium uptake by rice straw of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

The K uptake by rice strawwas higherin the second year compared to the first year with almost all treatments except T_6in Sara series and T_1, $T_6$and T_{10} treatments in Gopalpur series (Figure 4.48). The effect of chemical fertilizers + poultry manure treatment on the

K uptake by rice straw was statistically identical to the chemical fertilizers + cow dung and chemical fertilizers + oilcake treatments but superior to the rest of the treatments. The results indicated that K uptake was higher with the treatments comprised of chemical fertilizers and poultry manure than that of fertilizers applied by farmers or recommended fertilizers or soil test based fertilizer need. So, the uptake of K by rice straw may be improved by combined application of chemical fertilizers and organic manures. These results also support the findings of Panauallah*et al.*(2005) andSarker *et al.* (2015). Hasan *et al.* (2009) reported that the total uptake of potassium increased with the application of chemical fertilizers and manures.

4.4.2.2.4. Sulphur uptake by rice straw

Application of different treatments caused significant changes in S uptake by rice straw in both soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns (Appendices 4.13a and 4.13b).

In Sara series, S uptake by rice straw varied between 2.20 and 6.43 kg ha^{-1}in the first year and between 2.20 and 6.80 kg ha^{-1}in the second year. The highest total S uptake was found with T_5 (75% of farmers' practice + 75% recommended S & B + 2 t ha^{-1} oilcake) treatment, which was about 192% higher over control and the lowest value was observed with T_0 treatment in the first year. In the second year, the highest S uptake was also found with T_5 treatment, which was about 210% higher over the control treatment. The effect of this treatment was statistically similar to treatments T_4 receiving 75% of farmers' practice + 75% recommended S & B + 3 t ha^{-1} poultry manure, T_8receiving 75% of recommended fertilizers + 3 t ha^{-1} poultry manureand T_9 receiving 75% of recommended fertilizers + 2 t ha^{-1} oilcake. The S uptake in straw was higher in the second year than that of the first year with almost all the treatments except T_0 treatment (Figure 4.49 and Appendix 4.13a).

In Gopalpur series, there was statistically significant difference in S uptake by rice straw among different treatment combinations (Appendix 4.13b). In the first year, the highest S uptake by rice straw of 4.00kg ha^{-1} was observed with T_9 treatment receiving 75% of recommended fertilizers + 2 t ha^{-1} recommended oilcake and the lowest S uptake of 1.50 kg ha^{-1}which was noted with control treatment. The total S uptake varied from 1.42 kg ha^{-1} with T_0 treatment to 4.74 kg ha^{-1} with T_2(chemical fertilizers applied by farmers + recommended S & B) treatment (Figure 4.49 and Appendix 4.13b). The effect of T_2 treatment was statistically superior to all other treatments.

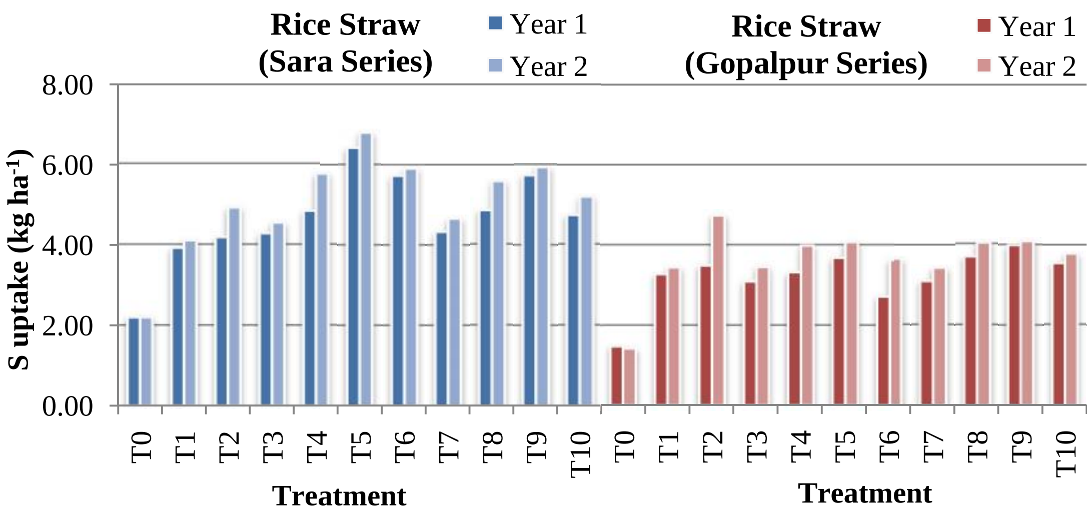

Figure 4.49. Sulphur uptake by rice straw of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.49 show that the S uptake was increased in the second year compared to first year in all the treatments except T_0 treatment under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns. The results proved that the significantly higherS uptake was found with the treatments comprised of chemical fertilizers and oilcake in Sara series than that of chemical fertilizer alone, but in case of Gopalpur series the S uptake was higher with only chemical fertilizers treated plots. The figure gives a clear indication that two different soils behaved differently for supplying the sulphur to rice crops under submerged condition, which may depend on its characteristics. These results corroborates well with the findings of Poongothai *et al.* (1999). They reported that application of S significantly increased S uptake by rice.

4.4.2.2.5. Zinc uptake by rice straw

The results of Zn uptake by rice straw in two different soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns are presented in Appendices 4.13a and 4.13b. The uptake of Zn by rice straw indicated significant variations among different treatments.

In Sara series, the highest Zn uptake of 346.08 g ha^{-1} in rice straw was recorded with T_5 (75% of farmers' practice + 75% recommended S & B + 2 t ha^{-1} oilcake) treatment and the lowest Zn uptake of 93.88 g ha^{-1} was observed with T_0 treatment in the first year (Figure 4.50 and Appendix 4.13a). The Zn uptake varied from 98.08 g ha^{-1} with T_0 treatment to 363.23 g ha^{-1} with T_5 treatment in the second year (Figure 4.50 and Appendix 4.13a). The results showed that the effect of T_5 treatment on Zn uptake by rice straw was statistically identical to T_4 (75% of farmers' practice + 75% recommended S & B + 3 t ha^{-1} poultry manure), T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) and T_9 (75% of recommended fertilizers + 2 t ha^{-1} oilcake) treatments but superior to the rest of the treatments.

In Gopalpur series, the uptake of Zn by rice straw varied from 68.64 to 213.55 g ha^{-1}in the first year and from 69.89 to 236.80 g ha^{-1}in the second year under different treatments (Figure 4.50 and Appendix 4.13b). The highest Zn uptake was found with T_8 treatment whose effect was statistically similar to all the treatments except T_0, T_3 and T_5 treatments and the lowest Zn uptake was observed in the control plot in both years (Figure 4.50 and Appendix 4.13b). The results indicated that the effect of chemical fertilizers and oilcake on Zn uptake by rice straw was better than only chemical fertilizers applied by farmers practice or recommended fertilizers or soil test based treatments.

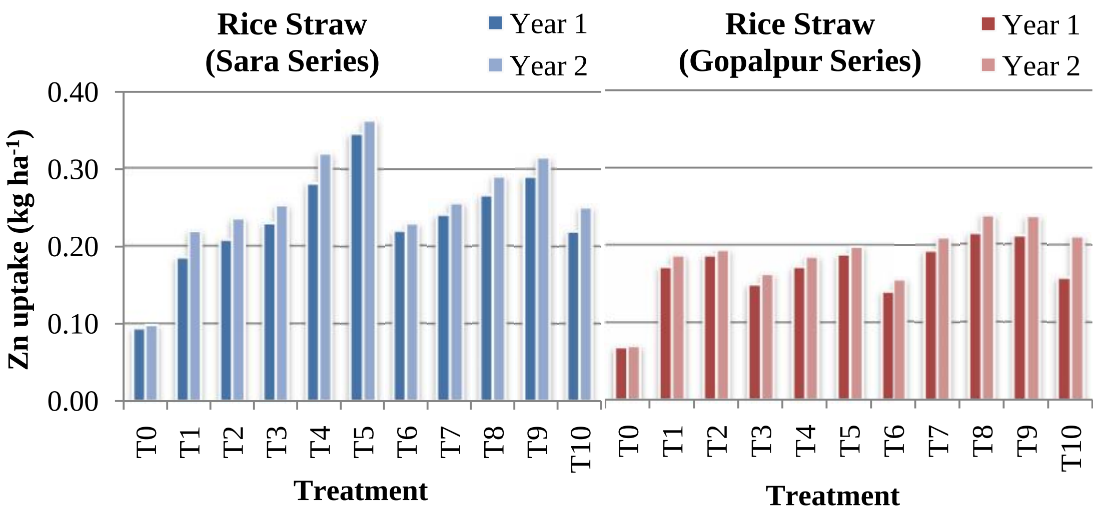

Figure 4.50. Zinc uptake by rice straw of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

Data presented in Figure 4.50 show that the zinc uptake by rice straw was statistically higher under combined application of chemical fertilizers and oilcake than that of other treatments. The treatment was followed by the combined application of chemical fertilizer with each of poultry manure and cow dung. The results indicated that the Zn uptake by rice straw increased in the second year than that of first year due to application of different treatments in both the soils. The results observed in this experiment were also supported by the findings of Dash *et al.* (2010). Bhuiyan*et al.* (2011) reported that the application of cow dung along with chemical fertilizers resulted in markedly higher uptake of Zn by T. aus rice.

4.4.2.2.6. Boron uptake by rice straw

The B uptake by rice straw was significantly influenced by different treatments applied through chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake in the first year of experiments, whereas the changes in B uptake values werenon-significant in the second yearin both the soils (Appendices 4.13a and 4.13b).

In Sara series, the B uptake by rice straw under Jute - T. aman - Mustard cropping pattern as affected by different treatments are presented in Appendices 4.13a. In the first year, the highest B uptake of 9.54 g $ha^{-1}$by rice straw was observed with T_8treatment comprisedof75% of recommended fertilizers + 3 t ha^{-1} poultry manureand the lowest value of 3.50 g ha^{-1} was found with T_0 treatment (Figure 4.51 and Appendix 4.13a). In the second year, the B uptake by rice straw ranged between 3.74 g ha^{-1} with T_0 treatment and 10.80 g ha^{-1} with T_8 treatment (Figure 4.51 and Appendix 4.13a). The highest B uptake by rice straw was recorded with T8 treatment which was statistically identical to all other treatments except T_0 (control) and T_7 (75% of recommended fertilizers + 5 t ha^{-1} cow dung) treatments. The levels of B uptake by rice straw improved in the second year compared to the first year in almost all treatments except T_5 and T_7 treatments.

In Gopalpur series, the B uptake by rice straw during two years of experiments as influenced by different treatments are given in Appendix 4.13b. The uptake of B by rice strawin the first and second years varied from 2.23 to 6.73 g ha^{-1} and 2.25 to 7.19 g ha^{-1}, respectively (Figure 4.51 and Appendix 4.13b). In the first year, the highest B uptake was found with T_4 treatment receiving 75% of farmers' practice + 75% recommended S & B + 3 t ha^{-1} poultry manure and the lowest B uptake was observed with the control treatment.

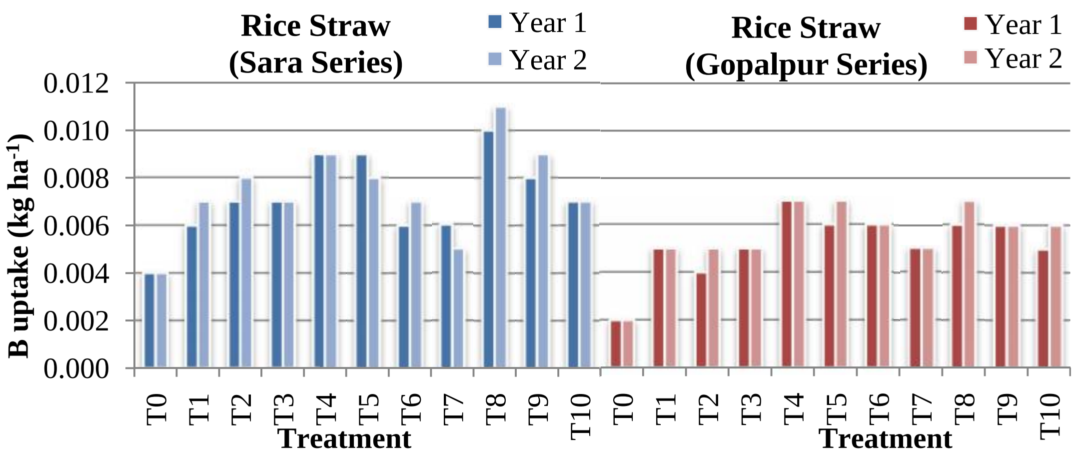

Figure 4.51. Boron uptake by rice straw of Sara and Gopalpur series as influenced by different treatments during two years of experiments.

In the second year, the highest B uptake (7.19 g ha^{-1}) was found with T_8 treatment (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) and the lowest B uptake (2.25 g ha^{-1}) was observed with the control treatment (Figure 4.51 and Appendix 4.13b). Therefore, the effect of 75% of recommended fertilizers + 3 t ha^{-1} poultry manure (T_8) treatment was statistically similar to all other treatments except T_0 treatment.

Figure 4.51 shows that the B uptake was increased in rice straw in the second year compared to the first year with almost all treatments used under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns except T_5 and T_7 treatments in Sara series. The higher value of B uptake was found with the chemical fertilizers +poultry manure oroilcake treatment compared to the other treatments. This might be happened due to higher availability of B in soil reservoir besides the additional quantity of B supplied by poultry manure.Bhuiyan*et al.* (2011) reported that the application of cow dung along with chemical fertilizers resulted in markedly higher uptake of B by T. aus rice.

4.4.3. Nutrients Uptake by Mustard

The nutrient uptake by grain and stover of mustard provided different results due to the application of different treatments with various concentrations. The nutrients uptake by grain and straw of mustard was calculated from their concentrations and yields data. Total uptake is the sum of grains and stover uptake data.

4.4.3.1. Nutrient Uptake by Mustard Grain

4.4.3.1.1. Nitrogen uptake by mustard grain

The nitrogen uptake by mustard grain was significantly influenced by different treatments applied in soils under Jute - T. aman - Mustard cropping pattern. The N uptake ranged from 9.33 to 52.11 kg ha^{-1} and 9.05 to 56.69 $kgha^{-1}$in the first year and second year, respectively (Figure 4.52 and Appendix 4.14). The highest N uptake for both years were observed with T_9 (75% of recommended fertilizers and 2 t ha^{-1} oilcake), which was statistically similar to the 75% of recommended fertilizers + 3 t ha^{-1} poultry manure (T_8) treatment but superior to the rest of the treatments. The lowest N uptakeby mustard grain for both years was found with T_0 treatment. These indicated that the chemical fertilizers + oilcake significantly influenced the N uptake by mustard grain.

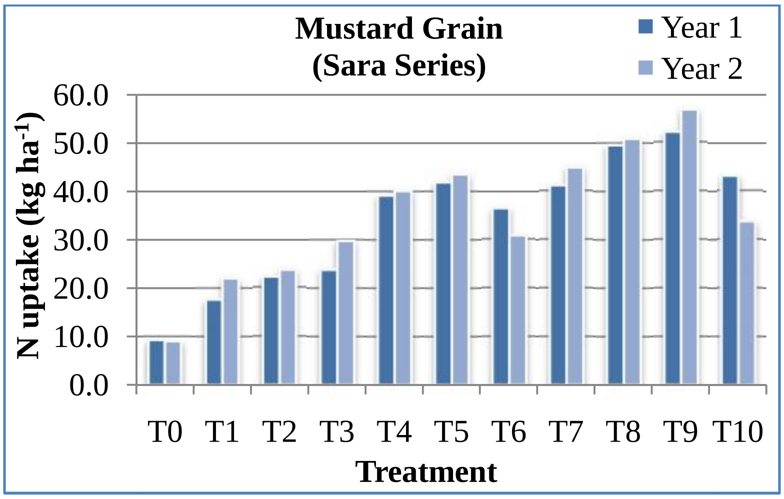

Figure 4.52. Nitrogen uptake by mustard grain of Sara series as influenced by different treatments during two years of experiments.

Figure 4.52shows that the N uptake by mustard grain increased in the second year compared to the N uptake in the first yearwith almost all the treatments except T_0, T_6 and T_{10} treatments. The results indicated that the N uptake was higher in treatments composed of chemical fertilizers and organic manures than that of fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers alone. The N uptake was significantly higher with chemical fertilizers + oilcake treatment compared to the chemical fertilizers + cow dung and chemical fertilizers + poultry manure treatments, which might be due to more nitrogen content in oilcake. The result also revealed that nitrogen uptake by grain was comparatively higher with the treatments composed of recommended chemical fertilizers and organic manures than that of other treatments.Zamil *et al.* (2004) reported that the highest uptake of N in stover and grain was obtained from cage system poultry manure @ 20 ton ha^{-1}.

4.4.3.1.2. Phosphorus uptake by mustard grain

There was a significant effect of different treatments through chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake on P uptake in two years under Jute - T. aman - Mustard cropping system(Appendix 4.14).The P uptake by mustard grain varied from 3.064 to 12.08 kg ha^{-1}in the first year and from 2.80 to 12.99 kg ha^{-1}in the second year. The highest P uptake for both years was recorded with T_9 (75% of recommended fertilizers and 2 t ha^{-1} oilcake) treatment but the effect of this treatment was statistically similar with the treatments T_5, T_8 and T_{10}. The lowest P uptake in both years was observed with T_0 (control) treatment (Figure 4.53 and Appendix 4.14).

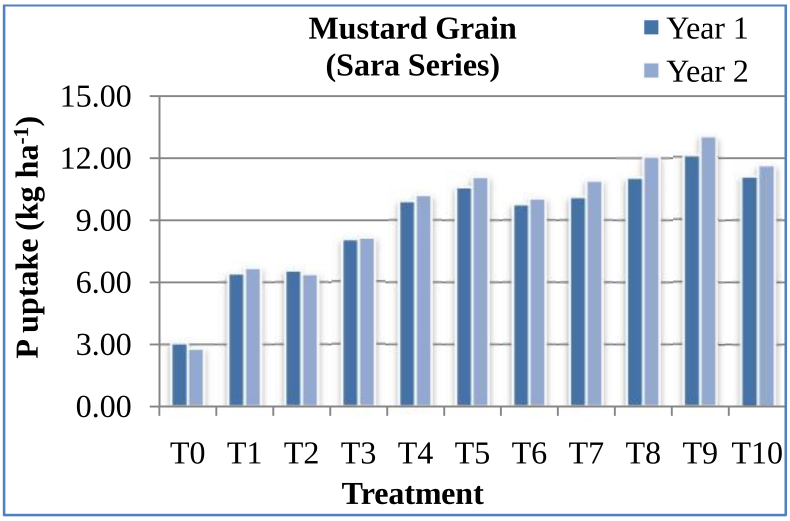

Figure 4.53. Phosphorus uptake by mustard grain of Sara series as influenced by different treatments during two years of experiments.

Figure 4.53 shows that P uptake by mustard grain was significantly higher in plots treated combinedly with chemical fertilizers and organic manures compared to the chemical fertilizer alone. The results indicated that the effect of chemical fertilizers + oilcake treatment on P uptake by grain was statistically identical to chemical fertilizers + poultry manure but superior to the rest of the treatments. The P uptake by grain in the second year increased compared to the P uptake in the first yearwith most of the treatments except T_0 and T_2 treatments. The highest uptake is an indication of higher availability of P that could easily be taken by mustard crop. Thus, the results of this study is in agreement with the findings ofZamil *et al.* (2004) who reported that the cage system poultry manure @ 20 ton ha^{-1} provided highest uptake of P in stover and grain.

4.4.3.1.3. Potassium uptake by mustard grain

The uptake of K by mustard grain as influenced by applied treatments is shown in Appendix 4.14. The uptake of K by grain was significantly affected due to application of different treatments in soils of Sara series under Jute - T. aman - Mustard cropping pattern. The K uptake by grain of mustard varied between 2.88 and 13.99 kg ha^{-1}in the first year and between 2.77 and 13.10 kg ha^{-1}in the second year(Figure 4.54 and Appendix 4.14). The highest grain K uptake was found with T_9 (75% of recommended fertilizers + 2 t ha^{-1} oilcake) treatment, which was statistically identical to T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment but superior to the rest of the treatments and lowest value was observed with T_0 (control) treatment in both years. The highest K uptake was about 386% higher over control.

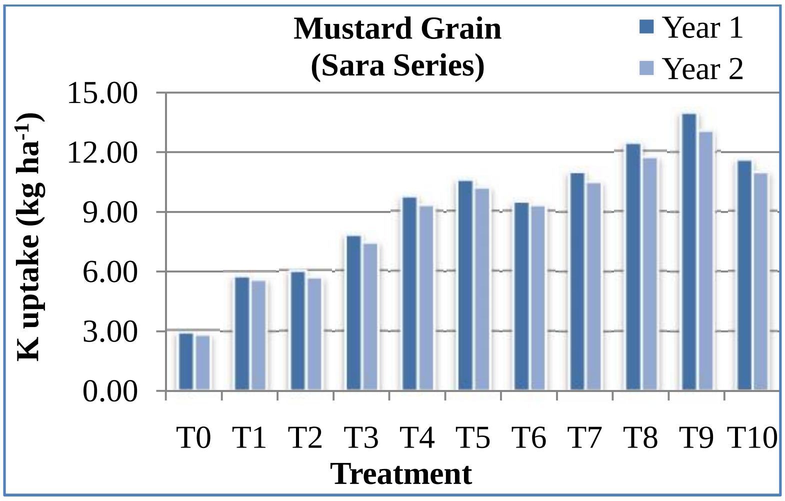

Figure 4.54. Potassium uptake by mustard grain of Sara series as influenced by different treatments during two years of experiments.

The K uptake by mustard grain was decreasedin the second yearcompared to the first year with all treatments (Figure 4.54).All the treatments showed higher K uptake by mustard grain over control. The figure showed that the highest K uptake in grain found withthe treatment comprised of recommended chemical fertilizers and oilcake, which followed by poultry manure based treatment. These results indicated that the K uptake by mustard grain was higher with chemical fertilizer plus organic manure treatments than that of only fertilizers applied by farmers or recommended fertilizers or soil test based treatments. Zamil *et al.* (2004) reported that the highest uptake of K by stover and grain was obtained from cage system poultry manure @ 20 ton ha^{-1}.

4.4.3.1.4. Sulphur uptake by mustard grain

The uptake of S by mustard grain under Jute - T. aman - Mustard cropping pattern was significantly influenced by different treatments comprised of chemical fertilizers in association with or without cow dung, poultry manure and oilcake (Appendix 4.15).In the first year, the highest uptake of 2.23 kg $ha^{-1}$was recorded with T_{10} (soil analysis based treatment) treatment, which increased the S uptake by 402% over control andthe lowest

S uptake of 0.45 kg ha^{-1} by mustard grain was recorded with the control treatment (Figure 4.55 and Appendix 4.15). In the second year, the S uptake by mustard grain ranged from 0.46 to 2.54 kg ha^{-1}(Figure 4.55 and Appendix 4.15). The S uptake was lowest with the control treatmentand the highest S uptake (2.54 kg ha^{-1}) was found with T_5(75% of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake)treatment, which was statistically superior to the other treatments.

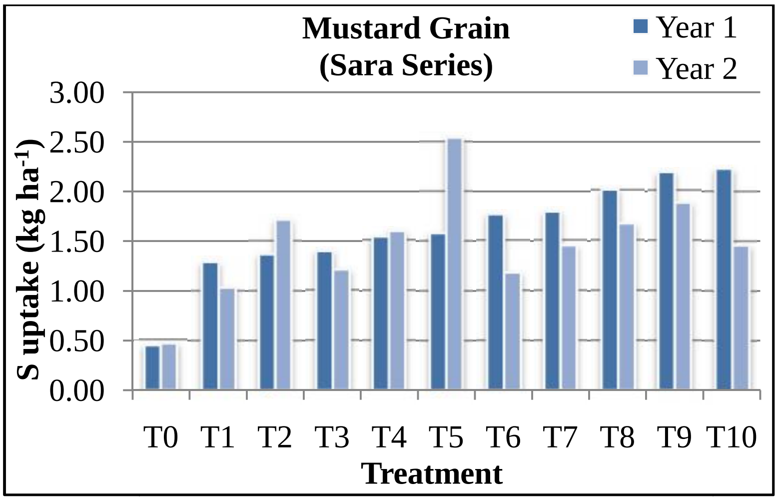

Figure 4.55. Sulphur uptake by mustard grain of Sara series as influenced by different treatments during two years of experiments.

Figure 4.55 shows that the S uptake decreased in the second year compared to first year under Jute - T. aman - Mustard cropping pattern with a few exception with T_0, T_2, T_4 and T_5 treatment. The average highest Suptake bymustard grainof two years was found with chemical fertilizer + oilcake treatment (T_5), which was significantly higher compared to the other treatments. The results indicated thatthe chemical fertilizers and oilcake based treatment was suitable for influencing the S uptake by mustard grain. The above discussion revealed that the complementary application of chemical fertilizers + organic manures (cow dung, poultry manure and oilcake) wasbetter for the S uptake by mustard grain.Similar result was also found by Zamil *et al.* (2004) in mustard grain and stover. Hossain *et al.* (2011) reported that the concentrations of S in mustard grain and stover were significantly increased with increased rate of boron application. These results are in agreement with those of Ganeshamurthy (1996) who reported that sulphur significantly increased the sulphur uptake.

4.4.3.1.5. Zinc uptake by mustard grain

Application of different treatments significantly influenced the Zn uptake by mustard grain in two years of experiments with Jute - T. aman - Mustard cropping pattern

(Appendix 4.15). The Zn uptake by mustard grain ranged from 11.47 to 61.32 g ha^{-1} and 13.17 to 63.53 g ha^{-1} in the first and second years, respectively (Figure 4.56 and Appendix 4.15). In both years, the highest Zn uptake was found with T_9 treatment (75% of recommended fertilizers + 2 t ha^{-1} oilcake), which was statistically identical to the 75% of recommended fertilizers + 3 t ha^{-1}poultry manure (T_8) treatment but superior to the other treatments and the lowest Zn uptake was recorded with T_0 treatment.

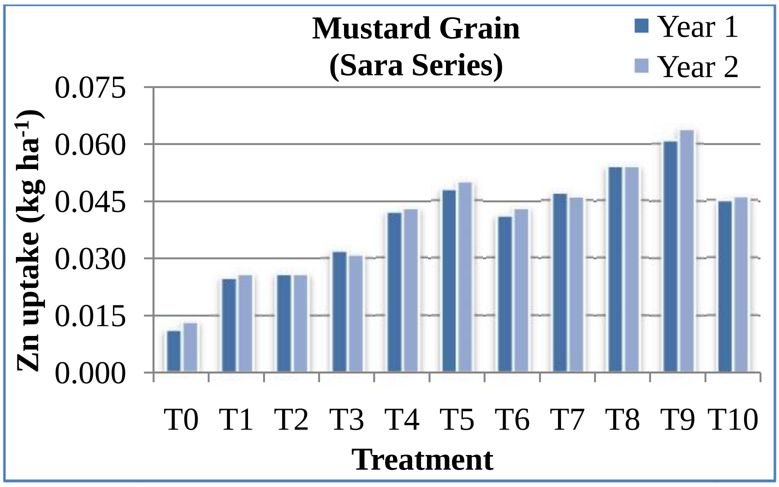

Figure 4.56. Zinc uptake by mustard grain of Sara series as influenced by different treatments during two years of experiments.

Figure 4.56 clearly shows that the Zn uptake by mustard grain in the second year was higher than that of first year in almost all treatments except T_3 treatment. The significantly higher value of Zn uptake by mustard grain was found with the treatments comprised of chemical fertilizers + oilcake, which was followed by chemical fertilizers + poultry manure and chemical fertilizers + cow dung treatments. The results revealed that mustard performed best in terms of Zn uptake with complementary application of chemical fertilizer and organic manures. This was happened due to higher availability of Zn in soil reservoir in addition to the additional quantity of Zn supplied by organic manures. Krishna and Singh (1992) reported that the Zn uptake by mustard grain was increased in both years due to Zn application.

4.4.3.1.6. Boron uptake by mustard grain

The results presented in Appendix 4.15 indicated that B uptake by mustard grainwas influenced significantly due to the application of different treatments in soils of Sara series under Jute - T. aman - Mustard cropping pattern.The B uptake bymustard grain ranged from 2.20 to 11.74 g ha^{-1}in the first year and from 2.21 to 11.08 g ha^{-1}in the second year (Figure 4.57 and Appendix4.15). In the first year, the highest B uptake

(11.74 g ha^{-1}) by grain was found with T_9 treatment receiving 75% of recommended fertilizers and 2 t ha^{-1} oilcakeand the lowest B uptake (2.20 g ha^{-1}) by mustard grain was found with T_0 treatment receiving no fertilizers or manure. In the second year, the minimumB uptake (2.21 g ha^{-1}) was found with T_0 treatment and the maximum of 11.08 g ha^{-1}by grain was recorded with T_4(75% of farmers' practice + recommended S & B + 3 t ha^{-1} poultry manure) treatment.

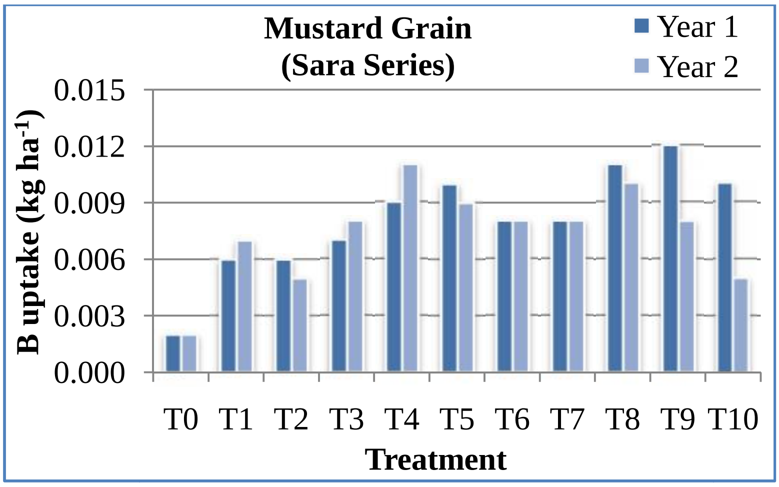

Figure 4.57. Boron uptake by mustard grain of Sara series as influenced by different treatments during two years of experiments.

Figure 4.57 shows that the B uptake by mustard grain was significantly higher with chemical fertilizers + oilcake treatmentwhich was followed by the chemical fertilizers + poultry manure treated plots. The B uptake by mustard grain was decreased in the second year compared to first year with most of the treatments except T_1, T_3, $T_4$and T_7 treatments.The results indicated that the combined application of chemical fertilizers and organic manures had significant influence on increasing the B uptake bymustard grain.

4.4.3.2. NutrientUptake by Mustard Stover

The nutrient contents and uptake by mustard stover increased with increasing application of that particular nutrient through chemical fertilizer or organic manures. The nutrient uptake by stover of mustard was calculated from their concentration and yield data.

4.4.3.2.1. Nitrogen uptake by mustard stover

The uptake of N by mustard stover indicated significant variations among different treatments applied during two years of experiments with Jute - T. aman - Mustard cropping pattern (Appendix4.16). In the first year, the highest N uptake of 38.00 kg ha^{-1} in mustard stover was recorded with T_9 (75% of recommended fertilizers + 2 t ha^{-1}

oilcake) treatment and the lowest N uptake of 10.72 kg ha^{-1} was observed with T_0 treatment (Figure4.58 andAppendix 4.16). In the second year, the N uptake varied from 9.92 kg ha^{-1} with T_0 treatment to 36.72 kg ha^{-1} with T_9 treatment (Figure4.58 andAppendix 4.16). The effect of recommended chemical fertilizers +oilcake (T_9) treatmentwas statisticallysimilar to T_5 (75% farmers' practice + 75% recommended S & B + 2 t ha^{-1} oilcake) treatments but superior to the rest of the treatments.

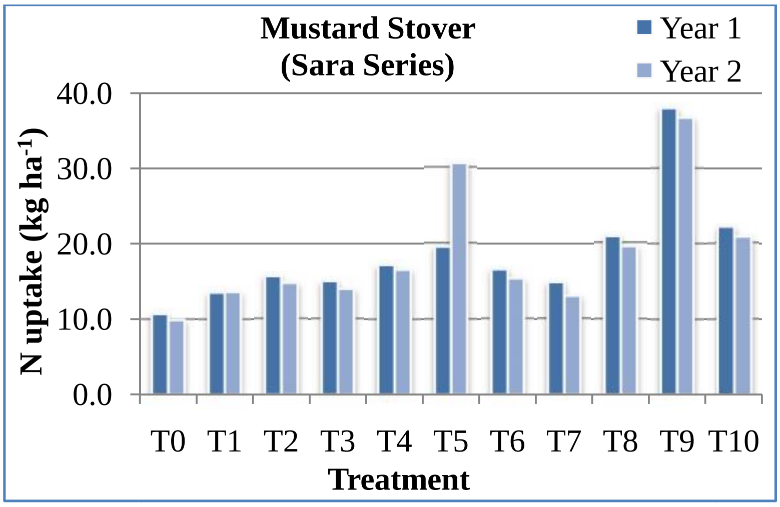

Figure 4.58. Nitrogen uptake by mustard stover of Sara series as influenced by different treatments during two years of experiments.

Figure 4.58 shows that the nitrogen uptake by mustard stover was significantly higher with the application of chemical fertilizers + oilcake treatment compared to the poultry manure and cow dung based treatments and also others. The second highest N uptake was observed with only chemical fertilizer treatment. The results indicated that the N uptake by mustard stover reducedin the second year than that of first year due to application of different treatments. These indicated that the use of oilcake with chemical fertilizers for mustard production system resulted in higher N uptake by stover.Zamil *et al.* (2004) reported that the highest uptake of N in stover of mustard was obtained from cage system poultry manure @ 20 t ha^{-1}.

4.4.3.2.2. Phosphorus uptake by mustard stover

The application of different treatments in different combinations of synthetic and organic fertilizers caused significant changes in P uptake by mustard stover during two years of experiments under Jute - T. aman - Mustard cropping pattern (Appendix 4.16). The P uptake by mustard stover varied between 0.60 and 3.19 kg ha^{-1} and between 0.53 and 0.3.42 kg ha^{-1} in the first and second years, respectively (Figure 4.59 and Appendix 4.16). In the first year trial, the lowest (0.60 kg ha^{-1}) and the highest P uptake (3.19 kg ha^{-1}) by mustard stover were found with T_0(control) and T_9 (75% of recommended fertilizers + 2 t ha^{-1} oilcake) treatments, respectively. In the second year trial, the highest P uptake was found with T_5 (75% of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake) treatment and the lowest value was observed with T_0 treatment. The effect of T_5treatment was statistically superior to other treatments.

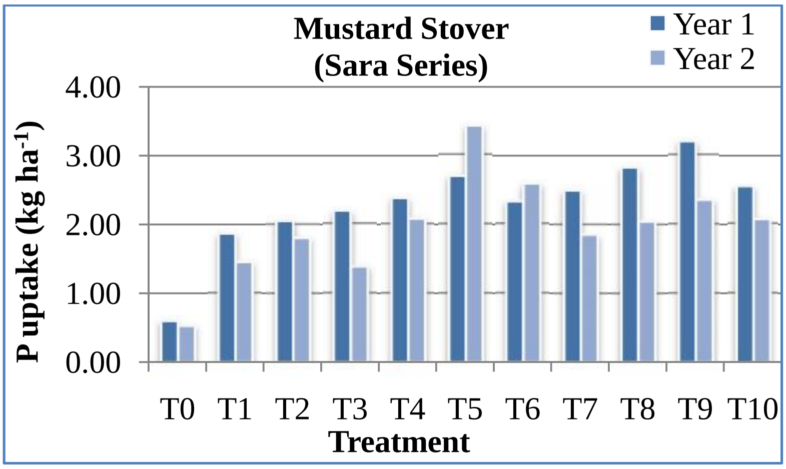

Figure 4.59. Phosphorus uptake by mustard stover of Sara series as influenced by different treatments during two years of experiments.

Figure 4.59 shows that P uptake by mustard stover was reduced in the second year compared to first year with almost all treatments except T_5 and T_6 treatments. The results indicated that the application of chemical fertilizers + oilcake and chemical fertilizers + poultry manure provided higher P uptake in mustard stover than that of the chemical fertilizer alone. However, the chemical fertilizers in association with organic manure performed better in respect of P uptake by mustard stover. Zamil *et al.* (2004) reported that the highest P uptake by mustard stover was resulted from cage system poultry manure @ 20 t ha^{-1}.

4.4.3.2.3. Potassium uptake by mustard stover

The effect of chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake on potassiumuptake by grain of T. aman rice was non-significant (Appendix 4.16).The K uptake by mustard stover under different treatments varied from 23.18 to 66.36 kgha^{-1}in the first year and20.75 to 93.72 kgha^{-1}in the second year (Figure 4.60 and Appendix 4.16). The highest K uptake recorded with T_9 (75% of recommended fertilizers and 2 t ha^{-1} oilcake) treatment in the first year and with T_5 (75% of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake) treatment in the second year. The lowest K uptake in mustard stover was observed with T_0 treatment receiving no fertilizer or manure. The effect of T_5treatment on K uptake by mustard stover was statistically superior to all other treatments.

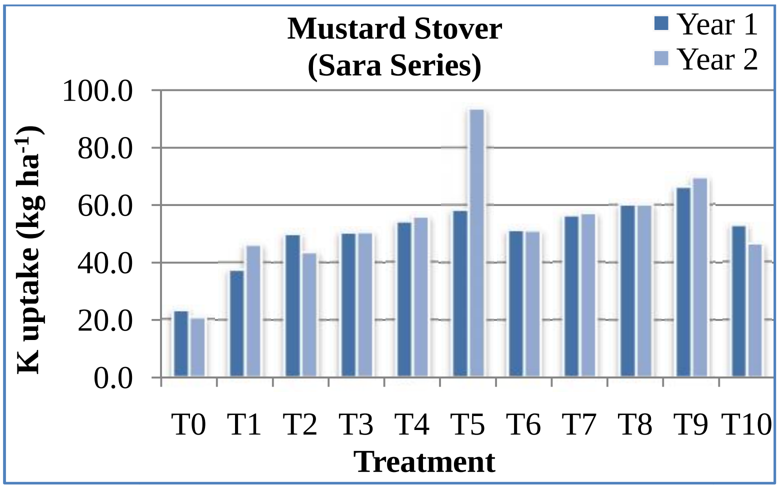

Figure 4.60. Potassium uptake by mustard stover of Sara series as influenced by different treatments during two years of experiments.

Figure 4.60 shows that the uptake of K by mustard stover was higher in plots treated with chemical fertilizers +oilcake compared to rest of the treatments, which was followed by chemical fertilizers + poultry manure and chemical fertilizers + cow dung.The effect of chemical fertilizers + organic manures on the K uptake by mustard stover was pronounced. The results providedan indication about the K uptake by mustard stoverwas increased in the second year than that of first year due to application of the treatments. Zamil *et al.* (2004) reported that the highest uptake of K in stover and grain of mustard was obtained from cage system poultry manure @ 20 t ha^{-1}.

4.4.3.2.4. Sulphur uptake by mustard stover

The S uptake by mustard stover varied significantly due to the influence of chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake in two years of experiments under Jute - T. aman - Mustard cropping pattern (Appendix 4.17). The maximum S uptake of 13.65kg $ha^{-1}$was recorded with T_9 (75% of recommended fertilizers + 2 t ha^{-1} oilcake) treatment and minimum S uptake of 3.32kg $ha^{-1}$with T_0 treatmentin the first year (Figure 4.61 and Appendix 4.17). In the second year, the highest S uptake of 16.00 kg $ha^{-1}$by mustard stover was recorded with T_5 (75% of farmers' practice + recommended S & B + 2 t ha^{-1} oilcake) treatment and the lowest S uptake of 3.05 kg $ha^{-1}$was found with T_0 treatment (Figure 4.61 and Appendix 4.17). The highest S uptake by mustard stover with T_5treatment was statistically superior toall other treatments.

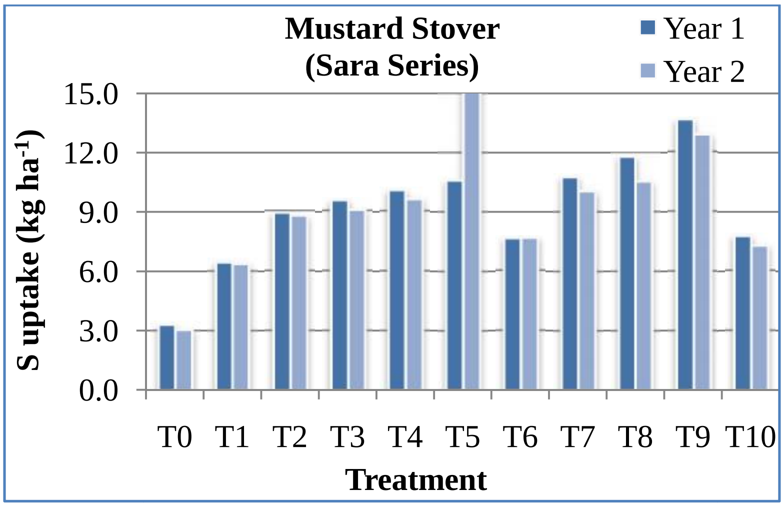

Figure 4.61. Sulphur uptake by mustard stover of Sara series as influenced by different treatments during two years of experiments.

Figure 4.61 shows that the S uptake by mustard stover decreasedin the second year compared to the first year in almost all treatments except T_5 and T_6 treatments. The results indicated that the S uptake was higher with the treatments comprised of chemical fertilizers and oilcake than that of others, which followed by chemical fertilizers + poultry manure and chemical fertilizers + cow dung. It is clear that the combined application of chemical fertilizers and organic manure treatments to mustard crop recorded high S uptake compared to only chemical fertilizer based treatments. Zamil *et al.* (2004) reported that the highest S uptake by mustard stover and grain was obtained from cage system poultry manure @ 20 t ha^{-1}.

4.4.3.2.5. Zinc uptake by mustard stover

The application of different treatments at different combinations caused significant changes in Zn uptake by mustard stover in soils under Jute - T. aman - Mustard cropping pattern during two years of experiments (Appendix 4.17). In the first year, the highest Zn uptake of 99.10 g $ha^{-1}$by mustard stover was observed with T_9 treatment receiving 75% of recommended fertilizers + 2 t ha^{-1} oilcake and the lowest Zn uptake of 34.63 g $ha^{-1}$was noted with control treatment (Figure 4.62 and Appendix 4.17). The Zn uptake varied from 31.18 g ha^{-1} with T_0 treatment to 112.94 g ha^{-1} with T_5 (75% of farmers' practice + 75% recommended S & B + 2 t ha^{-1} oilcake) treatment (Figure 4.62 and Appendix 4.17). The effect of T_5 treatment on Zn uptake by mustard stover was statistically similar to T_8 treatment but superior to all other treatment.

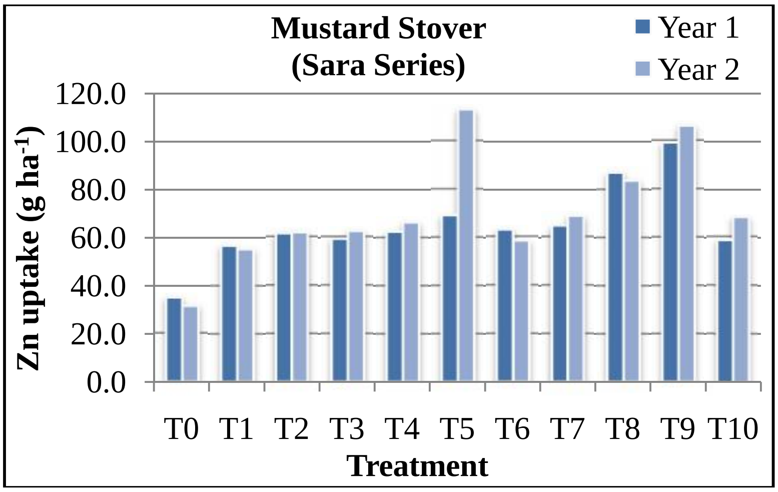

Figure 4.62. Zinc uptake by mustard stover of Sara series as influenced by different treatments during two years of experiments.

Figure 4.62 shows that the uptake of Zn by mustard stover was improved in the second year due to application of different treatments than that of first year with all the treatments except T_0, T_2 and T_6 treatments. The results proved that the higherZn uptake was found with the treatments comprised of chemical fertilizers and oilcake. The figure gives a clear indication that the application of organic manures increased the Zn uptake which might be due to greater availability of Zn present in the soil as well as in the organics.Krishna and Singh (1992) reported that the Zn application increased Zn content and uptake in seeds and stover of mustard in both years compared to the control.

4.4.3.2.6. Boron uptake by mustard stover

Data on B uptake by mustard stover due to various treatments are presented in Appendix 4.17 where non-significant effect on B uptake was observed in the first year and significant for second year. In the first year, the B uptake was non-significantly varied from 18.99 to 57.24 g ha^{-1} due to different treatments. The highest uptake of B by mustard stover was found with T_9 treatment and the lowest was observed with T_0 treatment (Figure 4.63 and Appendix 4.17). In the second year, the B uptake by mustard stover was observed to be influenced significantly by different treatments which varied from 18.55 to 76.76 g ha^{-1} (Figure 4.63 and Appendix 4.17). The highest and lowest B uptake by mustard stover was found with T_5 (75% of recommended fertilizers + 2 t ha^{-1} oilcake) and T_0 treatments, respectively. The B uptake by mustard stover with T_5 treatment was statistically identical to T_9 treatment but superior to the rest of the treatments.

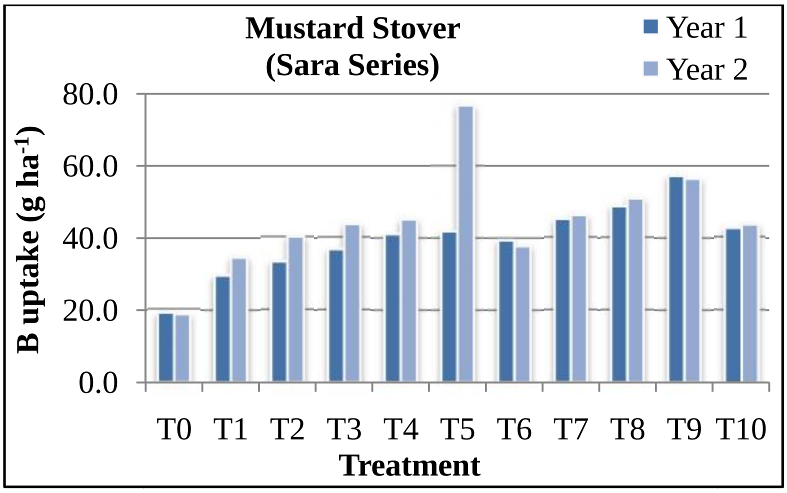

Figure 4.63. Boron uptake by mustard stover of Sara series as influenced by different treatments during two years of experiments.

The data revealed that the combined application of chemical fertilizer with oilcake (T_5 and T_9) brought about improved but non-significantB uptake by stover and established superiority over other treatments (Figure 4.63). The B uptake by stover in the second year was increased than that of first year in almost all treatments except T_6 and T_9 treatments. Higher B uptake by mustard stover might be due to the higher B content in oilcake than that of poultry manure and cow dung.

4.4.4. Nutrients Uptake byLentil

The uptake of nutrients by grain and stover of lentil increased with increasing application of a particular nutrient through chemical fertilizer or organic manures. The nutrient uptake by grain and straw of lentil was calculated from their concentrations and yields data. Total uptake by lentil is the sum of grain and stover uptake.

4.4.4.1. Nutrients Uptake by Lentil Grain

4.4.4.1.1. Nitrogen uptake by lentil grain

The use of chemical fertilizers individually or in combination with cow dung, poultry manure and oilcake showed significant difference of N uptake by lentil grainamong the treatments applied inJute - T. aman - Lentil cropping pattern. The N uptake by lentil grain significantly varied among the treatments and statistically higher amount of N uptake by grain was found with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment compared to the others (Appendix 4.18). The uptake of N by lentil grain ranged from 31.42 to 77.50 kg ha^{-1}in the first year and from 27.54 to 84.10 kg ha^{-1}in the second year under different treatments (Figure 4.64 and Appendix 4.18). The highest N uptake was found with T_8 treatment, which was statistically superior compared to the other treatments and the lowest N uptake was observed in the control plot in both years.

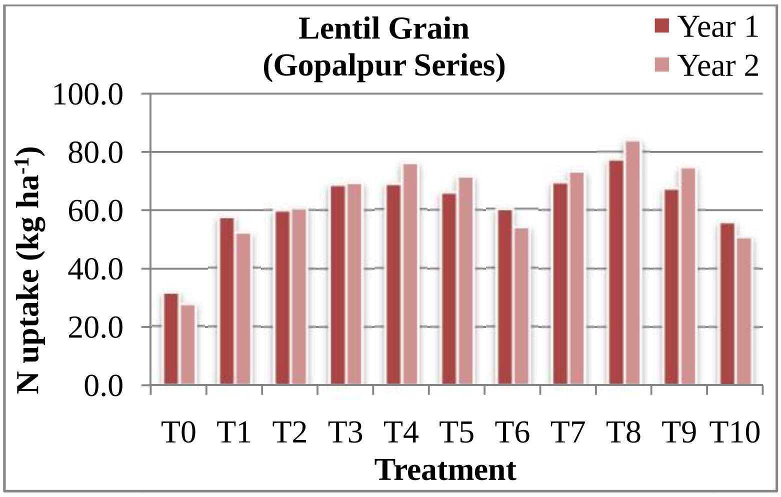

Figure 4.64. Nitrogen uptake by lentil grain of Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.64 shows that the N uptake by lentil grain was increased in the second year compared to first year in almost all treatments except T_0, T_1, T_6 and T_{10} treatments. The results indicated that N uptake by lentil grain with chemical fertilizers + poultry manure was statistically superior to other treatments, which was followed by cow dung and oilcake. The increased uptake of N suggests a positive effect of chemical fertilizers and poultry manure on N absorption by lentil crop. Upadhyay (2013) found that the nitrogen uptake by grain and straw increased significantly with increased levels of S and Zn upto 30 kg and 6 kg ha^{-1} application, respectively. The results are in agreement with Khatun *et al.* (2010), who reported that higher nitrogen uptake was associated with higher seed yield. Afzal *et al.* (2003) also reported similar results for nitrogen uptake in lentil.

4.4.4.1.2. Phosphorus uptake by lentil grain

Application of different treatments significantly increased the uptake of P by lentil grain over control in soils under Jute - T. aman - Lentil cropping pattern (Appendix 4.18). The P uptake by grain of lentil due to different treatment applications ranged from 1.68 to 5.61 kg ha^{-1} and 1.50 to 6.87 kg ha^{-1}in the first and second years, respectively (Figure4.65 and Appendix 4.18).The highest P uptake by lentil grain was observed with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment, which was statistically identical to T_3, T_4, T_5, T_7 and T_9 treatments but superior to the rest of the treatments and the lowest P uptake was found with T_0 treatment receiving no fertilizer or manure. The effect of chemical fertilizers + poultry manure treatment on P uptake by lentil grain was similar to chemical fertilizers + oilcake and chemical fertilizers + cow dung treatments.

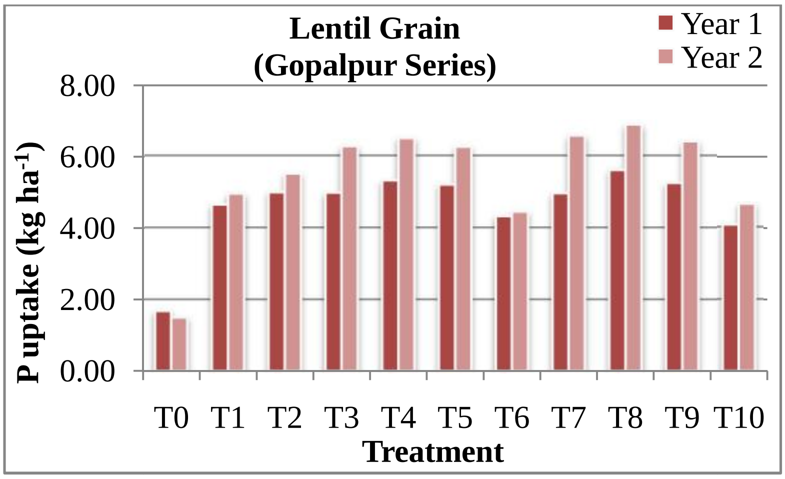

Figure 4.65. Phosphorus uptake by lentil grain of Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.65 shows that the combined application of chemical fertilizer and poultry manure played major role over other treatments in P uptake by lentil grain. The results indicated that the P uptake by lentil grain improved in the second year compared to the first year in almost all treatments except control treatment. The reason for increased uptake of P by lentil grain over control was probably due to the residual effect of readily decomposable manures. Haque and Khan (2012) reported that phosphatic biofertilizer with 50% P from TSP gave the highest total P uptake by lentil compared to the 100% P from TSP. Sarwar (2003) found that the effects of B levels and varieties on uptake of P by grain and stover were statistically significant.

4.4.4.1.3. Potassium uptake by lentil grain

The application of chemical fertilizers and organic manures through different treatment combinations significantly influenced the potassium uptake by lentil grain under Jute - T. aman - Lentil cropping pattern (Appendix 4.18).Plots amended with 75% of recommended fertilizers + 3 t ha^{-1} poultry manure (T_8) treatment yielded highest value of 7.22 kg ha^{-1}K uptake and the lowest value of 3.36 kg ha^{-1} was found with T_0 amended plots in the first year. The highest K uptake was statistically similar with T_7(75% of recommended fertilizers + 5 t ha^{-1} cow dung) treatment. In the second year, the K uptake by lentil grain ranged between 2.93 kg ha^{-1} with T_0 treatment and 7.59 kg ha^{-1} with T_7 treatment (Figure 4.66 and Appendix 4.18). The highest value with T_7 treatment was statistically similar to T_3, $T_4$and T_8 treatmentsbut superior to the rest of the treatments.

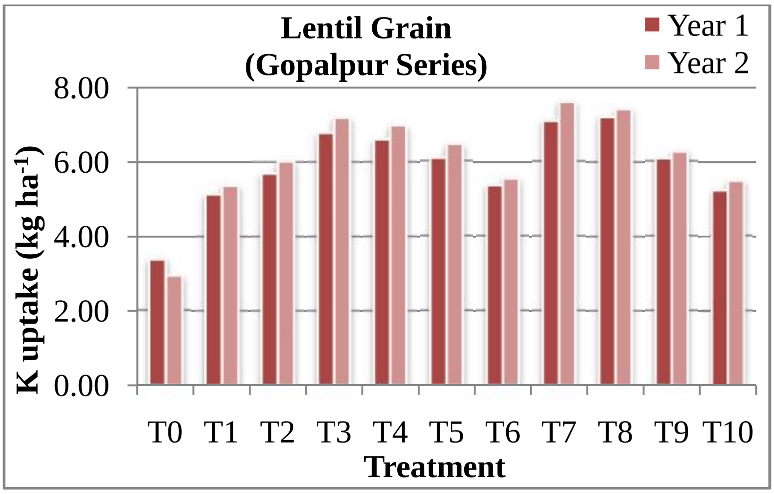

Figure 4.66. Potassium uptake by lentil grain of Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.66 shows that the K uptake by lentil grainincreasedin the second year compared to first year in all the treatments used in soils under Jute - T. aman - Lentil cropping pattern. The figure also shows that the uptake of K by lentil grain was markedly influenced by the combined application of chemical fertilizers and organic manures compared to chemical fertilizer alone. The highest K uptake was found with the treatments comprised of chemical fertilizers and cow dung, because of high K content in cow dung. The results indicated that the application of organic sources significantly increased the uptake of K by lentil grain.Upadhyay (2013) reported that successive levels of S and Zn increased the potassium uptake by lentil grain and straw significantly.

4.4.4.1.4. Sulphur uptake by lentil grain

The sulphuruptake by lentil grain during two years of experiments as influenced by different treatments is given in Appendix 4.19. The uptake of S by lentil grain in the first and second years varied from 0.66 to 2.12 kg ha^{-1} and 0.65 to 2.28 kg ha^{-1}, respectively (Figure 4.67 and Appendix 4.19). The highest S uptake by lentil grain was found with T_8 treatment receiving 75% of recommended fertilizers + 3 t ha^{-1} poultry manureand the lowest S uptake was observed with the control treatment in both years. The S uptake by lentil grain due to the application of T_8treatment was statistically similar to all the treatments except T_0, T_1, T_6 and T_{10} treatments.

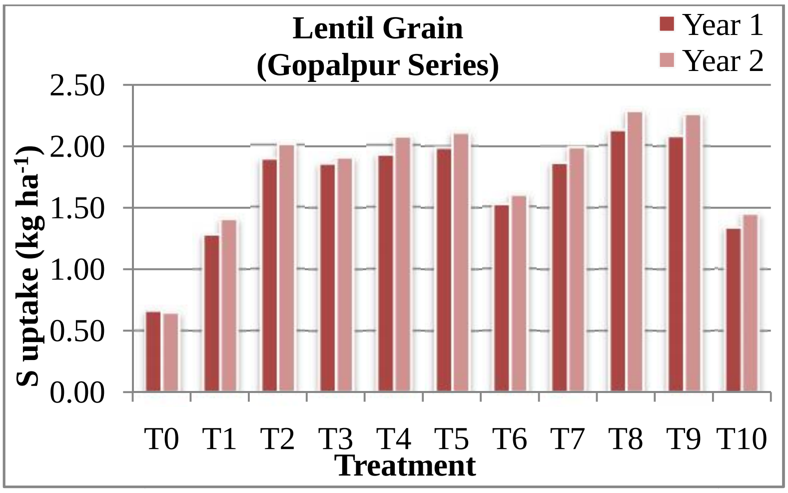

Figure 4.67.Sulphur uptake by lentil grain of Gopalpur series as influenced by different treatments during two years of experiments.

Data presented in Figure 4.67 show that the S uptake was increased in the second year compared to first year in almost all treatments used in lentil production system except T_0 treatment. The significantly highest value of S uptake was found with the treatments comprised of chemical fertilizers and organic manures than that of chemical fertilizer alone. Therefore, the combined application of chemical fertilizers and poultry manure (T_8) treatment showed a better effect on S uptake over other treatments. This was happened due to higher availability of S in soil reservoir besides the additional quantity of S supplied by poultry manure. These results are in agreement with those of Ganeshamurthy (1996) who reported that sulphur significantly increased the sulphur uptake. Upadhyay (2013) reported that sulphur uptake increased significantly with increasing levels of S up to 30 kg ha^{-1} over control.

4.4.4.1.5. Zinc uptake by lentil grain

The application of different treatments had significant effects on the Zn uptake by lentil grain during two years of experiments withJute - T. aman – Lentil cropping pattern (Appendix 4.19). The uptake of Zn by lentil grain ranged from 30.28 to 79.27 g ha^{-1} and from 30.97 to 82.73 g ha^{-1}in the first and second years, respectively (Figure 4.68 and Appendix 4.19). In both years, the highest Zn uptake was observed with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment, which was statistically similar to all other treatments except T_0 treatment and the lowest uptake was recorded with the control treatment.

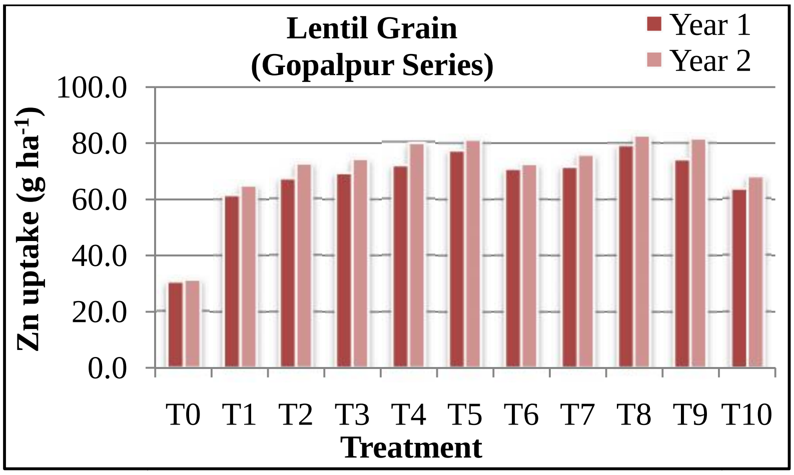

Figure 4.68. Zinc uptake by lentil grain of Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.68 shows that the Zn uptake by lentil grain during two years of experiments was increased in the second year compared to first year. It was clear from the above figures and results that there was no mentionable effect of chemical fertilizer alone or in combination with organic manures in increasing the uptake of Zn by lentil grain, though the combined application of chemical fertilizers and poultry manure provided the highest Zn uptake. Among the organic sources, the performance of poultry manure was better than other two manures i.e. cow dung and oilcake in two years of experiments.Upadhyay (2013) reported that the uptake of Zn by lentil grain and straw increased significantly with S application and maximum value was recorded at 20 kg S ha^{-1}.

4.4.4.1.6. Boron uptake by lentil grain

The data in Appendix 4.19 show a variation in boron (B) uptake by lentil grain from year to year and from treatment to treatment under Jute - T. aman - Lentil cropping pattern. In the first year trial, the highest B uptake of 3.11 g ha^{-1} by lentil grain was observed with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment, which was statistically similar with T_9 treatment and the lowest B uptake of 0.83 g ha^{-1} by grain was recorded with T_0 treatment (Figure 4.69 and Appendix 4.19). In the second year, the B uptake by lentil grain varied from 0.79 to 3.28 g ha^{-1} (Figure 4.69 and Appendix 4.19). The highest B uptake by grain was also found with T_8 treatment, whose effect was statistically similar to all other treatments except T_0 treatment. The lowest B uptake was observed with the control plot.

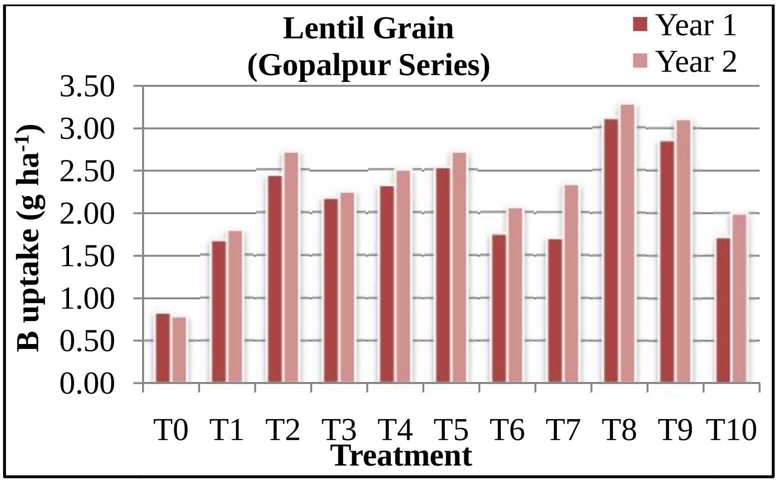

Figure 4.69. Boron uptake by lentil grain of Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.69 shows that the B uptake by lentil grain was found significantly higher with chemical fertilizers + poultry manure which was statistically similar to the chemical fertilizers + oilcake treatment. But, the uptake of B by grain might be improved due to combined application of chemical fertilizers and organic manures. This was happened due to higher availability of B in soil reservoir besides the additional quantity of B supplied by fertilizer and manures. Sarwar (2003) found that the effects of B levels and varieties on uptake of B by grain and stover were statistically significant.

4.4.4.2. Nutrient Uptake by Lentil Stover

The nutrient content and uptake by lentil stover increased with increasing application of that particular nutrient through chemical fertilizer or organic manures. The nutrients uptake by stover of lentil was calculated from their concentration and yield data. Total uptake by lentil is the sum of grains and stover uptake.

4.4.4.2.1. Nitrogen uptake by lentil stover

The nitrogen uptake by lentil stover increased significantly with the application of different treatments in soils under Jute - T. aman - Lentil cropping pattern (Appendix 4.20). In the first year, the N uptake by lentil stover varied from 8.81 to 18.54 kg ha^{-1} due to different treatments (Figure70 and Appendix 4.20). The lowest and highest N uptake were found with T_0(control) and T_4treatments(75% of farmers' practice + 75% recommended S & B + 3 t ha^{-1} poultry manure), respectively. In the second year, the highest N uptake of 17.00 kg ha^{-1} by lentil stoverwas found with T_9(75% of recommended fertilizers + 2 t ha^{-1} oilcake) treatment, which was statistically similar to

T_4, T_5, T_7, $T_8$and T_{10}treatments but superior to the rest of the treatments, and the lowest N uptake of 8.03 kg ha^{-1} by stover was recorded with T_0 treatment.

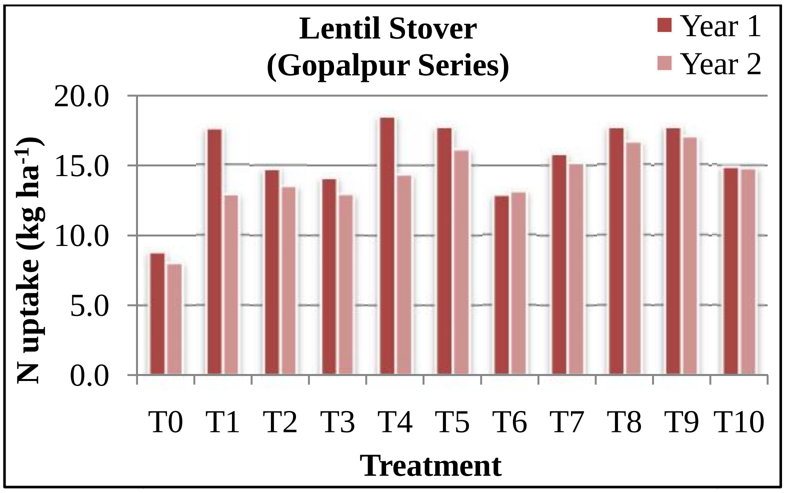

Figure 4.70. Nitrogen uptake by lentil stover of Gopalpur series as influenced by different treatments during two years of experiments.

An examination of data presented in Figure 4.70revealed that the combined application of chemical fertilizers and poultry manure had remarkable effect on N uptake by lentil stover over other amendments. The results show that the N uptake by stover wasreducedin the second year compared to the first year in almost all treatments. The average data of two years indicated that the combined application of chemical fertilizers + oilcake and chemical fertilizers + poultry manure were more effective for N uptake by lentil stover, which was probably due to the large quantity of N supply through organic manures. Sarwar (2003) found that the effects of B levels and varieties on uptake of N by grain and stover were also statistically significant. Afzal *et al.* (2003) also reported similar results for nitrogen uptake in lentil. Upadhyay (2013) found that the nitrogen uptake by lentil grain and straw increased significantly with increased levels of S and Zn upto 30 kg and 6 kg ha^{-1} application, respectively.

4.4.4.2.2. Phosphorus uptake by lentil stover

A significant difference in P uptake by lentil stover was observed with different treatments applied through chemical fertilizers alone or in combination with cow dung, poultry manure and oilcake (Appendix 4.20).In the first year, the P uptake by stover of lentil ranged from 0.43 to 1.31 kg ha^{-1} due to different treatment combinations (Figure 4.71 and Appendix 4.20). The highest P uptake (1.31 kg ha^{-1}) was recorded with T_4 treatment receiving 75% of farmers' practice + 75% recommended S & B + 3 t ha^{-1}

poultry manure, which was statistically identical to T_1, T_3 and T_5 treatments and the lowest P uptake (0.43 kg ha^{-1}) was observed with T_0 treatment. In the second year, the highest P uptake of 1.52 kg $ha^{-1}$was observed with T_4 treatment and the lowest uptake of 0.38 kg ha^{-1} with control treatment (Figure 4.71 and Appendix 4.20).

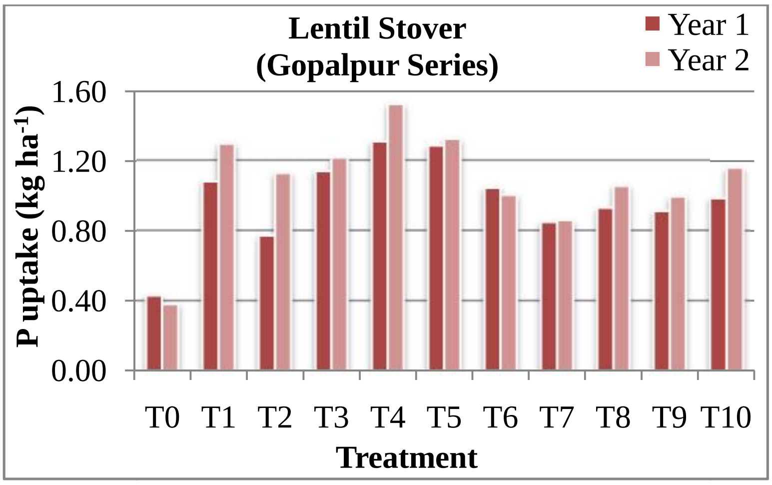

Figure 4.71. Phosphorus uptake by lentil stover of Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.71 shows that the P uptake by lentil stover increased in the second year than that of first year under Jute - T. aman - Lentil cropping pattern in all treatments except T_0 treatment. The P uptake by lentil stover was higher in chemical fertilizer + poultry manure (T_4) treatment over other treatments. The results indicated that the combined application of chemical fertilizers and poultry manure may influence the P uptake by lentil stover and were significantly superior to other treatments. Upadhyay (2013) reported that the application of sulphur significantly increased the uptake of P by lentil crop over control. Application of phosphatic biofertilizer increased P uptake by the different crops is also reported by many workers (Kundu *et al.*, 2006).

4.4.4.2.3. Potassium uptake by lentil stover

The results presented in Appendix 4.20 showed that K uptake by lentil stover differed significantly due to application of different treatments during two years of experiments with Jute - T. aman - Lentil cropping pattern. The K uptake by lentil stover varied from 5.37 to 11.01 kg ha^{-1}in the first year and from 4.96 to 11.31 kg ha^{-1}in the second year of experiments (Figure 4.72 and Appendix 4.20). In the first year, the highest K uptake (11.01 kg ha^{-1}) by stover was recorded with T_8 treatment receiving 75% of recommended fertilizers + 3 t ha^{-1} poultry manure and the lowest value (5.37 kg ha^{-1}) of K uptake was recorded with T_0treatment. In the second year, the lowest K uptake (4.96 kg ha^{-1}) was rerecorded with control treatment and the highest K uptake (11.31 kgha^{-1}) was observed with T_8 treatment. The effect of T_8 treatment on K uptake by lentil stover was statistically similar to all other treatments except T_0, T_5, T_6 and T_{10} treatments.

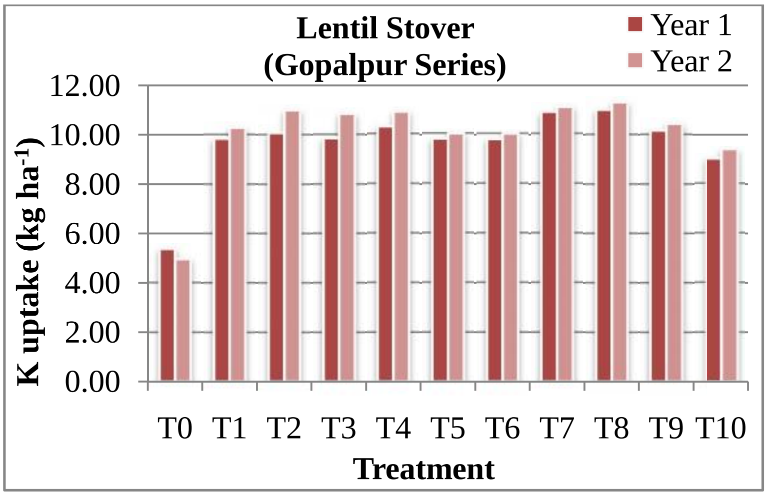

Figure 4.72. Potassium uptake by lentil stover of Gopalpur series as influenced by different treatments during two years of experiments.

Data presented in Figure 4.72 shows that the K uptake by lentil grain during two years of experiments was increased in the second year compared to first year in all treatments except T_0 treatment. The combined application of chemical fertilizers and poultry manure provided highest K uptake compared to other treatments. Among the organic manures, performance of poultry manure was better than other two manures i.e. cow dung and oilcake in two years of experiments. It was clear from the above figures and results that the application of chemical fertilizer in combination with poultry manure had mentionable effect on increasing the uptake of K by lentil stover.Sarwar (2003) found that the effects of B levels and varieties on uptake of K by grain and stover were also statistically significant. Upadhyay (2013) reported that the K uptake by lentil grain and straw was affected significantly by S and Zn application.

4.4.4.2.4. Sulphur uptake by lentil stover

The uptake of S by lentil stover was significantly affected due to application of different treatments in two years under Jute - T. aman - Lentil cropping pattern (Appendix 4.21). The S uptake by lentil stover ranged from 0.79 to 1.51 kg ha^{-1}in the first year (Figure 4.73 and Appendix 4.21). The highest S uptake by lentil stover was observed with T_9 (75% of recommended fertilizers and 2 t ha^{-1} oilcake) treatment and the lowest S uptake by lentil stover was recorded with T_0 (control) treatment. In the second year, the S uptake by lentil stover varied from 0.80 to 1.57 kg ha^{-1} under different treatments (Figure 4.73

and Appendix 4.21). The maximum S uptake by lentil stover was recorded with T_9 treatment, which was statistically similar to T2, T4, T_5, T_6, $T_7$and T_8 treatments but superior to the rest of the treatments. The minimum S uptake by lentil stover was recorded with T_0 treatment.

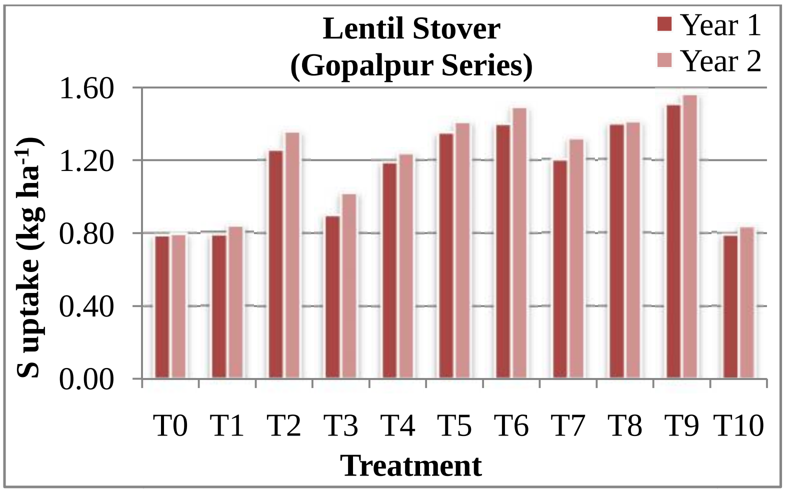

Figure 4.73. Sulphur uptake by lentil stover of Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.73 shows that the S uptake by lentil stover increased in the second year compared to first year in soils under Jute - T. aman - Lentil cropping pattern. The highest Suptake by stover was found with chemical fertilizer + oilcake (T_9) treatment. It is clear from the results that the chemical fertilizer + oilcake provided significantly higher S uptake by lentil stover than that of other treatments. These results are in agreement with those of Ganeshamurthy (1996) who reported that sulphur significantly increased the sulphur uptake. Upadhyay (2013) also reported that sulphur uptake increased significantly with increasing levels of S up to 30 kg ha^{-1} over control.

4.4.4.2.5. Zinc uptake by lentil stover

The uptake of Zn by lentil stover grown in Gopalpur series soil under Jute - T. aman - Lentil cropping pattern was significantly influenced by different treatments comprised of chemical fertilizers in association with or without cow dung, poultry manure and oilcake (Appendix 4.21). In the first year, the Zn uptake by lentil stover ranged from the lowest value of 14.37 g ha^{-1} with T_0 (control) treatment to the highest value of 43.70 g ha^{-1} with T_9 (75% of recommended fertilizers + 2 t ha^{-1} oilcake) treatment (Figure 4.74 and Appendix 4.21). In the second year, Zn uptake varied between 15.38 g ha^{-1} with T_0 treatment and 46.77 g ha^{-1} with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment (Figure 4.74 and Appendix 4.21). The highest Zn uptake by lentil stover with T_8 treatment was statistically identical to the treatments T_4, T_5, T_6, T_9 and T_{10} but superior to rest of the treatments.

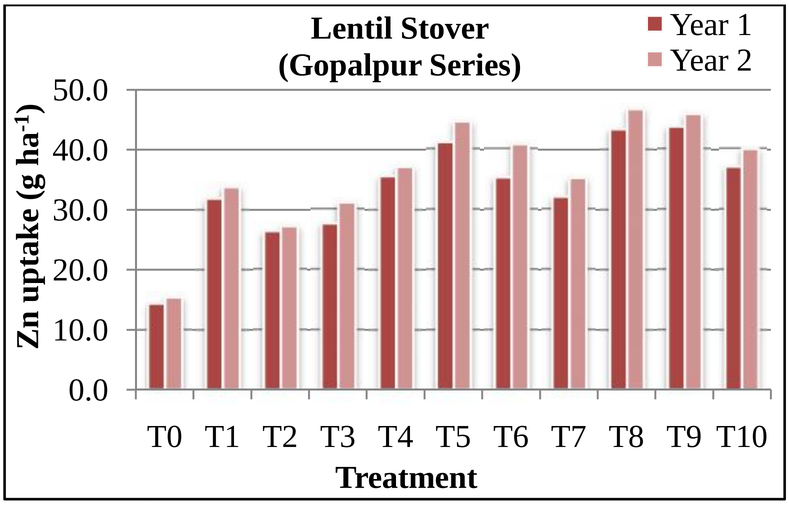

Figure 4.74. Zinc uptake by lentil stover of Gopalpur series as influenced by different treatments during two years of experiments.

Data presented in Figure 4.74 show that the Zn uptake by lentil stover was reduced in the second year compared to first year in all treatments. The results showed that the effect of chemical fertilizer and oilcake on the Zn uptake by lentil stover was superior to all other treatments. The higher Zn uptake obtained with the application of oilcake and poultry manure with chemical fertilizers might be in harmony with supply of nutrients at a rate sufficient to support the growth of lentil. Upadhyay (2013) reported that the uptake of Zn by lentil grain and straw increased significantly with S application and maximum values were recorded at 20 kg S ha^{-1}.

4.4.4.2.6. Boron uptake by lentil stover

There was non-significant effect of different treatment combinations applied through chemical fertilizers alone or in combination with organic manure on B uptake by lentil stover during two years of experiments with Jute - T. aman - Lentil cropping pattern (Appendix 4.21). In the first year trial, the highest B uptake of 16.96 g ha^{-1} by lentil stover was recorded with T_9 treatment (75% of recommended fertilizers + 2 t ha^{-1} oilcake) and the lowest B uptake of 5.22 g ha^{-1} by lentil stover was found with the control (T_0) treatment (Figure 4.75 and Appendix 4.21). In the second year trial, the maximum B uptake of 17.45 g ha^{-1} by lentil stover was found with T_9 treatment and the minimum B uptake of 5.10 g ha^{-1} was noted with control treatment (Figure 4.75 and Appendix 4.21).

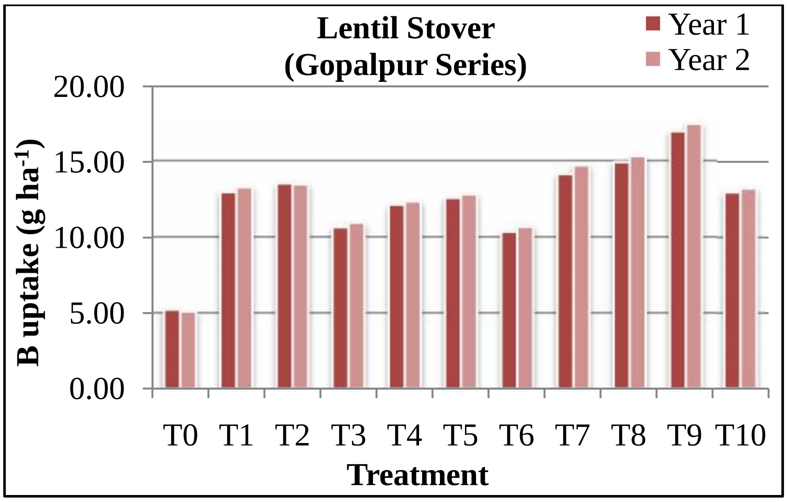

Figure 4.75. Boron uptake by lentil stover of Gopalpur series as influenced by different treatments during two years of experiments.

Figure 4.75shows that there was no remarkable B uptake by lentil stover during two years of experiments. The results indicated that the combined application of chemical fertilizers and oilcakenon-significantly influenced the B uptake by lentil stover. However, the chemical fertilizers in association with oilcake performed better in respect of B uptake by lentil stover. Sarwar (2003) found that the effects of B levels and varieties on uptake of B by grain and stover of lentil were statistically significant.

4.4.5. Ca, Mg, Fe, Mn and CuConcentrations and Uptake by Crops

Beside the above mentioned nutrient elements, the concentrations and uptake of Ca, Mg, Fe, Mn and Cu by jute, rice, mustard and lentil were also determined and presented in Appendices 4.22 to 4.35. As the Ca, Mg, Fe, Mn and Cu containing fertilizers were not applied during the field experiments, so these nutrients were not discussed in detailed in this chapter. But it is also mentionable that with a few exceptions, the application of different treatments had significant effect on Ca, Mg, Fe, Mn and Cu concentrations and uptake by jute stick with bark, mustard grain and stover, and lentil grain and stover. The results also indicated that the concentrations and uptake of Ca, Mg, Fe, Mn and Cu by rice grain and straw were influenced non-significantly due to the application of different treatments in almost all cases.

4.4.6. Total Uptake of Nutrients

The total uptake of nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, iron, manganese, zinc, copper and boron by crops grown in Jute - T. aman - Mustard cropping pattern in Sara series and Jute - T. aman - Lentil cropping pattern in Gopalpur series during two years of field experiments are presented in Table 4.1 and 4.2. Essentially, the higher nutrient uptake was observed in those treatments that produced the higher biomass.

The amounts total uptake of N, P, K, S, Ca, Mg, Fe, Mn, Zn, Cu and B by the crops of Jute - T. aman - Mustard cropping pattern were higher in the second year compared to the first year of experiments and varied from 90.64 – 283.11 kg ha^{-1}, 15.35 – 48.22 kg ha^{-1}, 126.23 – 410.72 kg ha^{-1}, 13.50 – 46.07 kg ha^{-1}, 75.33 – 214.28 kg ha^{-1}, 10.68 – 39.54 kg ha^{-1}, 1.57 – 5.06 kg ha^{-1}, 0.480 – 1.503 kg ha^{-1}, 0.277 – 0.907 kg ha^{-1}, 0.088 – 0.251 kg ha^{-1}, and 0.130 – 0.468 kg ha^{-1}, respectively due to different treatments (Table 4.1). The lowest nutrient uptake were found with T_0 (control) where as the highest amounts uptake of N, K, Mn and Zn were observed with T_9 (75% of recommended fertilizers + 2 t ha^{-1} oilcake) treatment and the contents of total uptake of P, S, Ca, Mg, Fe and Cu were found with T_5 (75% of farmers' practice + 75% recommended S & B + 2 t ha^{-1} oilcake) treatment (Table 4.1). The results indicated that the effect of chemical fertilizers and oilcake ($T_9$and T_5) on the total uptake of majority nutrients was better than any other treatments.

The total uptake of nutrients by crops of Jute - T. aman - Lentil cropping pattern varied among the treatments and increased in the second year than the first year except control (Table 4.2). The highest total uptake of N (261.67 kg ha^{-1}) and Cu (0.270 kg ha^{-1}) was found with T_9 treatments (75% of recommended fertilizers + 2 t ha^{-1} oilcake) treatment, total uptake of P (48.29) and B (0.348 kg ha^{-1}) was observed with T_4 treatment receiving 75% of farmers' practice + 75% recommended S & B + 3 t ha^{-1} poultry manure**, and** total uptake of K (345.18 kg ha^{-1}), S (25.34 kg ha^{-1}), Ca (160.91 kg ha^{-1}), Mg (24.26 kg ha^{-1}), Fe (1.697 kg ha^{-1}), Mn (1.027kg ha^{-1}) and Zn (0.726 kg ha^{-1}) was found with T_8 (75% of recommended fertilizers + 3 t ha^{-1} poultry manure) treatment compared to the other treatments (Table 4.2). The data indicated that the highest total uptake of majority nutrients was observed with combined application of recommended fertilizers and poultry manure (T_8) in both year.

Table 4.1. Total uptake of nutrients by Jute-T. aman-Mustard cropping pattern of Sara Series as influenced by treatment T_0, T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9 and T_{10} during two years of field experiments.

Nutrients	Total Uptake of Nutrients (kg ha^{-1})										
	Treatment										
	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Year-1 (Jute-T. aman-Mustard cropping pattern)											
Nitrogen	93.33	182.47	164.47	178.12	200.67	248.27	219.29	230.66	215.99	270.52	198.92
Phosphorus	16.14	29.00	32.17	39.45	38.64	46.45	36.55	39.53	44.15	42.25	36.77
Potassium	137.10	287.78	310.92	332.89	362.10	386.65	361.72	395.36	389.37	401.02	305.05
Sulphur	14.01	27.54	30.10	31.41	30.33	38.08	33.82	37.26	39.78	42.80	29.74
Calcium	77.82	104.20	128.66	137.49	147.20	166.95	129.86	151.20	154.23	182.87	125.66
Magnesium	11.37	21.59	25.04	23.81	31.15	31.79	27.70	27.60	31.89	33.22	26.55
Iron	1.564	2.901	2.960	3.345	3.579	3.774	3.360	3.687	4.008	4.248	3.414
Manganese	0.484	0.915	0.987	1.102	1.216	1.388	1.121	1.122	1.243	1.489	1.157
Zinc	0.280	0.524	0.569	0.579	0.669	0.778	0.631	0.705	0.712	0.763	0.623
Copper	0.092	0.177	0.165	0.178	0.198	0.229	0.190	0.179	0.200	0.227	0.194
Boron	0.136	0.181	0.223	0.283	0.312	0.269	0.245	0.334	0.399	0.333	0.204
Year-2 (Jute-T. aman-Mustard cropping pattern)											
Nitrogen	90.64	192.86	167.69	189.17	210.00	270.66	211.13	231.26	226.11	283.11	187.65
Phosphorus	15.35	30.21	32.21	39.86	38.85	48.22	37.93	40.93	42.94	41.53	34.81
Potassium	126.23	317.72	359.63	374.61	380.62	410.51	295.54	398.02	350.22	410.72	288.54
Sulphur	13.50	26.81	33.36	34.15	35.82	46.07	33.24	39.36	39.92	43.08	30.87
Calcium	75.33	111.96	148.86	163.64	155.46	214.38	159.42	175.38	155.88	214.28	128.50
Magnesium	10.68	24.62	24.51	24.31	31.00	39.54	26.19	29.00	30.89	38.13	25.10
Iron	1.567	2.927	3.231	3.375	3.654	5.058	3.430	3.685	3.951	4.289	3.360
Manganese	0.480	0.961	1.010	1.090	1.247	1.391	1.171	1.153	1.266	1.503	1.171
Zinc	0.277	0.602	0.621	0.666	0.764	0.876	0.655	0.726	0.803	0.907	0.756
Copper	0.088	0.197	0.175	0.192	0.205	0.272	0.207	0.200	0.199	0.251	0.211
Boron	0.130	0.194	0.276	0.331	0.392	0.342	0.232	0.316	0.468	0.358	0.192

T_0 : Control;
T_1 : Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) + recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 : Recom. fertilizer nutrients;
T_7 : Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 : Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 : Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Table 4.2. Total uptake of nutrients by Jute-T. aman-Lentil cropping pattern of Gopalpur Series as influenced by treatment T_0, T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9 and T_{10} during two years of field experiments.

Nutrients	Total Uptake of Nutrients (kg ha^{-1})										
	Treatment										
	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Year-1 (Jute-T. aman-Lentil cropping pattern)											
Nitrogen	107.15	209.58	203.58	214.00	206.95	235.42	208.30	223.47	233.68	240.40	186.55
Phosphorus	14.23	29.82	29.55	33.06	48.29	33.58	29.91	32.49	42.44	34.57	31.07
Potassium	112.38	255.02	215.01	276.54	285.41	277.20	243.52	211.57	238.72	271.04	239.26
Sulphur	11.18	20.36	18.40	18.45	21.68	22.48	19.55	20.31	25.24	24.20	21.36
Calcium	62.55	84.47	102.88	93.96	114.97	115.04	98.45	99.41	126.73	113.54	97.50
Magnesium	10.06	18.60	19.89	19.42	22.05	22.95	21.21	20.90	23.72	23.29	20.21
Iron	0.735	1.188	1.202	1.414	1.559	1.518	1.416	1.481	1.624	1.532	1.316
Manganese	0.327	0.697	0.772	0.813	0.992	1.083	0.804	0.759	1.029	1.068	0.743
Zinc	0.241	0.521	0.564	0.526	0.635	0.582	0.545	0.611	0.670	0.660	0.530
Copper	0.078	0.162	0.173	0.187	0.210	0.232	0.188	0.197	0.233	0.248	0.165
Boron	0.113	0.166	0.212	0.281	0.333	0.198	0.252	0.215	0.319	0.227	0.207
Year-2 (Jute-T. aman-Lentil cropping pattern)											
Nitrogen	101.13	209.72	215.29	226.65	228.18	262.71	210.00	241.03	254.37	261.67	195.86
Phosphorus	13.27	27.61	32.19	35.70	44.86	35.94	30.24	35.33	44.76	36.03	32.83
Potassium	108.18	251.62	244.31	258.97	287.41	271.59	250.04	261.74	345.18	294.65	263.38
Sulphur	10.70	19.49	22.21	19.33	23.65	23.02	20.69	21.25	25.34	24.73	20.34
Calcium	60.84	122.19	109.59	105.62	132.73	127.04	100.50	109.46	160.91	128.64	122.59
Magnesium	9.63	18.90	20.78	19.45	22.45	23.09	19.87	21.07	24.26	23.00	21.09
Iron	0.727	1.215	1.206	1.486	1.651	1.600	1.420	1.572	1.697	1.597	1.332
Manganese	0.313	0.724	0.807	0.848	1.010	1.104	0.771	0.751	1.027	1.100	0.763
Zinc	0.239	0.538	0.627	0.565	0.674	0.641	0.586	0.633	0.726	0.716	0.614
Copper	0.077	0.171	0.183	0.199	0.227	0.253	0.190	0.217	0.248	0.270	0.184
Boron	0.110	0.170	0.228	0.305	0.348	0.216	0.259	0.295	0.347	0.243	0.220

T_0 : Control; T_1 : Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) + recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 : Recom. fertilizer nutrients; T_7 : Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 : Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 : Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

The appliedcow dung, poultry manure and oilcake had influence on the yields as well as nutrient content and uptake underJute - T. aman - Mustard and Jute - T. aman - Lentil production system atSara and Gopalpur series of Lower Ganges River Floodplain Soils (AEZ 12). The results of nutrient contents and uptake study showed that continuous use of organic manures along with chemical fertilizers increased nutrients concentrations and uptake by crops under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns than that of sole application of chemical fertilizers (fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers). The major nutrients N, P, K and S concentration and uptake by jute, rice, mustard and lentil were significantly higher with combined application of chemical fertilizers and organic manures compared to only fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers treatments.With some deviations in level of significance, the minor nutrients (Fe, Mn, Zn, Cu and B)content and uptake by jute, rice, mustard and lentil were also significantly influenced by the combined application of chemical fertilizer and organic manure. The results also indicated that the behavior of thesoils of two different series was different in respect to supply of nutrients and consequent uptakeby crops upon addition of different treatment combinations.The present experiments revealed that three crops under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns can easily be grown through ensuring regular supply of organic manures with chemical fertilizers.

4.5. Apparent Nutrient Balances

A simplified approach was used to calculate partial net N, P, K, S, Zn and B balances based on major inputs: chemical fertilizers and organic manures (cow dung, poultry manure and oilcake), and major outputs (aboveground plant uptake). The results of apparent balance sheet of N, P, K, S, Zn and B prepared for Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns from two years of experiments are presented in Table 4.3 to 4.8.

4.5.1. Apparent Balance of Nitrogen (N)

The results of apparent N balance under two cropping patterns from two years of field experiments are presented in Table 4.3. Chemical fertilizer either singly or in combination with organic manures was the source of nitrogen addition, and much of the applied N was lost from the soil by removal through crops in Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns. The N balance measured from the addition and removal was different with different treatments.

In Sara series, the apparent N balance was ranged from -93.33 to 258.53 kg $ha^{-1}$and 90.63 to 245.94 kg ha^{-1} in the first and second years, respectively (Table 4.3). The highest positive N balances in Jute - T. aman - Mustard cropping pattern was found in the soils treated combinedly with 75% of recommended fertilizers and 2 t ha^{-1} oilcake (T_9) and the lowest balance was observed with the control in both years. However, the N balance was negative with those treatments composed of only chemical fertilizers i.e. fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers or controltreatments (Table 4.3).

In Gopalpur series, the apparent N balance was ranged from – 107.14 to 236.15 kg ha^{-1}in the first year and - 101.13 to 214.88 kg ha^{-1} in the second year (Table 4.3). The highest positive N balance wasobservedwith T_9 treatment receiving75% of recommended fertilizers + 2 t ha^{-1} oilcake and the lowest balance was found with the control in both years. The negative N balance was also recorded with those treatments composed of only chemical fertilizers applied by farmers, soil analysis based treatment and control, which might be due to addition of below optimum level of N added from only chemical fertilizer (120.26 – 181.34 kg ha^{-1} yr^{-1}) as shown in Table 4.3.

The data indicated that the apparent N balance was positive with the combined application of chemical fertilizers and organic manures, where sole chemical fertilizers (recommended fertilizers or farmers' practice) or control showed negative N balance. Nitrogen replenishment through chemical fertilizers with cow dung, poultry manure and oilcake was enough to balance N removal by crop. The treatments where oilcake (5.18% N content) and cow dung (1.63% N content) were added in intensive cropping systems showed a high positive N balance, where the poultry manure (1.44% N content) demonstrated a lower positive or negative N balance.The N balance thus was positive with those treatments appeared to have been removed a portion of the quantity added in soil. Present findings are also in agreement with the observation of Jahan *et al.* (2015), Zhao*et al.* (2011), Rahman *et al.* (2009) and Saha *et al.* (2007), where negative N balances in cropping systems were mentioned.

4.5.2. Apparent Balance of Phosphorus (P)

The application of different treatments yielded positive P balance in almost all treatments except T_0 treatment in Jute - T. aman - Mustard cropping patternand T_0 and T_{10} treatments in Jute - T. aman - Lentil cropping pattern.

In Sara series, the apparent balance of P resulted from the different fertilizer management practices varied from -16.15 to 106.89 kg ha^{-1} in Jute - T. aman - Mustard cropping pattern during two years of experiments (Table 4.4). The highest positive P balance was observed with 75% of farmers' practice + 75% of recommended S & B + poultry manure treated plots (T_4), which was followed by 75% of farmers' practice + 75% of recommended S & B + cow dung and 75% of farmers' practice + 75% of recommended S & B + oilcake treatments, and the lowest value of P balance (negative) was recorded with the control under intensive cropping practices. The incorporation of poultry manure, oilcake and cow dung with 75% farmers' chemical P fertilizer were good enough to maintain P balance in soil, which might be due to addition of extra nutrient in the range of 74.25 - 145.53 kg P $ha^{-1}yr^{-1}$ in Jute - T. aman - Mustard cropping pattern (Table 4.4).

In Gopalpur series, the P balance varied from -14.24 to 100.67 kg ha^{-1} in Jute - T. aman - Lentil cropping pattern resulted from different fertilizer management practices during two years of experiments (Table 4.4). The highest positive P balance was found with 75% of farmers' practice + 75% of recommended S & B + poultry manure (T_4) treated plots and the lowest value of P balance was observed with the control in intensive cropping systems. The addition of extra nutrient in the range of 76.50 - 145.53 kg P $ha^{-1}yr^{-1}$ in the Jute - T. aman - Lentil cropping pattern through application of poultry manure, oilcake and cow dung with 75% chemical P fertilizer were good enough to maintain the P balance in soil (Table 4.4).

The data indicated that the reduction of P fertilizer application by 25% and incorporation of organic manures (cow dung, poultry manure and oilcake) increased P balance in both soil series. The results revealed that the combined application of chemical fertilizers and organic manures yielded higher positive P balance where only chemical fertilizers (fertilizers applied by farmers or recommended fertilizers or soil test based fertilizers) provided lower P balance in two years of experiments. The apparent P balance with most of the treatments decreased in the second year compared to the first year. This type of result was obtained by Jahan *et al.* (2015), Singh*et al*. (2015), Husnain *et al.*, (2010), Rahman *et al.* (2009) and Saha *et al.* (2007). They reported that the positive P balance was likely due to the adequate replenishment through fertilizer P.

4.5.3. Apparent Balance of Potassium (K)

Apparent balance of K of Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns for two years is presented in Table 4.5. It was evident that K was removed in large excess of the amount added as fertilizer alone or in combination with manures in most of the treatments.

In Sara series, the highest negative K balance of -310.52 kg $ha^{-1}yr^{-1}$ was observed with 75% of recommended fertilizers+ oilcake (T_9) treatment and the lowest negative K balance of -92.86 kg $ha^{-1}yr^{-1}$due to addition of cow dung with chemical fertilizer (T_3) treatment in both years of experiments (Table 4.5). The total quantity of added K ranged from 0 to 249.03 kg $ha^{-1}yr^{-1}$ and the uptake by crops varied from 126.20 to 410.72 kg $ha^{-1}yr^{-1}$ in two years of experiments (Table 4.5).

In Gopalpur series, the apparent balance of K in soil was highly negative with all treatments which ranged from -263.38 kg $ha^{-1}yr^{-1}$with T_{10} treatment receiving soil analysis based fertilizer to -4.57 kg $ha^{-1}yr^{-1}$with T_7 treatment receiving 75% of recommended fertilizer + cow dung for Jute - T. aman - Lentil cropping pattern in two years of experiments (Table 4.5). The negative balance was shown lower in those treatments where cow dung (1.04% K content) was incorporated with chemical fertilizer compared to other treatment combinations. It might be happened due to the addition of extra K in the range of 216.00 to 240.03 kg $ha^{-1}yr^{-1}$ through chemical fertilizer (75%) + cow dung incorporation (Table 4.5).

The results indicated that the crops under intensive cropping removed more K compared to the applied amount. Therefore, a negative balance was observed for K after each year of experiments. Therefore, it is necessary to adjust the K fertilizer dose carefully to avoid K deficiency in soils. The results showed that negative K balance can be lower, if cow dung applied in combination with chemical fertilizer to the soils. These results confirmed the reports by Jahan *et al.* (2015), Singh*et al*. (2015), Husnain *et al.*, (2010), Rahman *et al.* (2009), Panaullah*et al.* (2007) and Saha *et al.* (2007). They indicated apparent negative K balances and ongoing K depletion in many intensive cropping systems.

4.5.4. Apparent Balance of Sulphur (S)

Apparent balance of sulphur under Jute - T. aman - Mustard and Jute - T. aman - Lentilcropping patterns for two years of experiments are presented separately in Table 4.6.

In Sara series, the S added as chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake ranged from 0.0 to 73.80 kg $ha^{-1}yr^{-1}$ for Jute - T. aman - Mustard cropping pattern. Total S uptake by the crops under the cropping pattern was 13.49 – 46.07 kg $ha^{-1}yr^{-1}$ and hence, the apparent S balance varied from -30.87 to 31.49 kg $ha^{-1}yr^{-1}$in two years of experiments (Table 4.6). Therefore, both positive and negative balances in soil were observed for S after the harvest all crops in a year under the cropping pattern. The highest positive S balance was recorded with T_5 treatment receiving 75% of farmers' practice + 75% of recommended S & B + 2 t ha^{-1} oilcake and lowest negative balance of S was found with T_{10} treatment receiving soil analysis based fertilizer. The negative S balances were also observed with T_0 and T_1 treatments in two years of experiments (Table 4.6).

In Gopalpur series, the apparent S balance ranged from -21.36 to 51.85 kg $ha^{-1}yr^{-1}$ for Jute - T. aman - Lentil cropping pattern in two years of experiments(Table 4.6). The S added as chemical fertilizer alone or in combination with cow dung, poultry manure and oilcake ranged from 0.0 to 76.05 kg $ha^{-1}yr^{-1}$ and total S uptake by crops was 10.70 – 51.85 kg $ha^{-1}yr^{-1}$ in two years. The T_9 treatment (75% of recommended chemical fertilizer and 2 t ha^{-1} oilcake) yielded maximum positive balance of S and T_{10} treatment provided the lowest negative S balance. The negative S balances were also observed with T_0, and T_1 treatments in two years (Table 4.6).

The reduction of S fertilizer application by 25% from the recommended S fertilizer and addition of recommended oilcake (T_9) treatment increased S balance in soil for both cropping patterns. Similar results were also found by Jahan *et al.* (2015), Rahman *et al.* (2009) and Saha *et al.* (2007), where positive S balance was found with combined application of chemical fertilizers and organic manures.

4.5.5. Apparent Balance of Zinc (Zn)

In Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns, the positive Zn balance of soil was found with almost all treatments except the control and considerable net gain of Zn was observed after two years of experiments (Table 4.7).

In Sara series, the amount of Zn added through different Zn treatments varied from 0.0 to 8.20 kg $ha^{-1}yr^{-1}$ and uptake ranged from 0.28 to 0.91 kg $ha^{-1}yr^{-1}$ with different treatments for Jute - T. aman - Mustard cropping pattern (Table 4.7). The only negative balance (-0.28 kg $ha^{-1}yr^{-1}$) was noticed with the control, which indicated the lowest value. Other treatments showed positive Zn balance which ranged from 1.35 to 7.53 kg $ha^{-1}yr^{-1}$in two years of experiments (Table 4.7). The highest positive Zn balance (7.53kg $ha^{-1}yr^{-1}$) were recorded with T_4 treatment receiving 75% of farmers' practice + 75% of recommended S & B + poultry manure which was followed by T_3 treatment composed of 75% of farmers' practice + 75% of recommended S & B + cow dung and the lowest positive balance (1.35 kg $ha^{-1}yr^{-1}$) was found with T_6 (recommended chemical fertilizers) treatment.

In Gopalpur series, the highest positive Zn balance of 7.57 kg $ha^{-1}yr^{-1}$ with T_4 treatment (75% of farmers' practice + 75% recommended S & B + 3 t ha^{-1} poultry manure), and the lowest and only negative balance of -0.24 kg $ha^{-1}yr^{-1}$ was noticed with the control under Jute - T. aman - Lentil cropping pattern after two years of experiments (Table 4.7). The amount of Zn added through different Zn treatments varied from 0.0 to 8.20 kg $ha^{-1}yr^{-1}$ and uptake ranged from 0.24 to 0.73 kg $ha^{-1}yr^{-1}$ with different treatments (Table 4.7). The lowest positive Zn balance of 1.41 kg $ha^{-1}yr^{-1}$ was recorded with T_6treatment receiving recommended chemical fertilizers.

The above discussion revealed that the apparent Zn balance can be higher, if the soils treated combinedly with chemical fertilizer and poultry manure i.e. organic manure. Similar results were reported by Jahan *et al.* (2015) in T. aman rice based cropping pattern and Saha *et al.* (2007) in dry season rice (Boro)–green manure (GM)–wet season rice (T. aman) cropping system.

4.5.6. Apparent Balance of Boron (B)

The values of apparent B balance due to application of different treatments in Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patternsafter two years of experiments are presented in Table 4.8. In Sara series, a considerable amount of B was added to soils under Jute - T. aman - Mustard cropping pattern in each year of experiments. The range of added boron was 0.0 to 1.20 kg $ha^{-1}yr^{-1}$ and the uptake ranged from 0.13 to 0.47 kg $ha^{-1}yr^{-1}$ in two years of experiments (Table 4.8). Thus, the apparent B balance varied from -0.20 to0.89kg ha^{-1}, wherethe highest value was found with 75% of farmers' practice + 75% of recommended S & B + poultry manure (T_4) treatment. The lowest and negative balance of B was recorded with T_2(75% of farmers' practice + 75% of recommended S & B) treatment. It was observed that the balance was negative with all plots treated with chemical fertilizer alone.

In Gopalpur series, the apparent B balance varied from -0.22 to 0.94 kg ha^{-1} in Jute - T. aman - Lentil cropping pattern after each year of experiments and the highest apparent positive B balance was observed with 75% of recommended fertilizers + cow dung (T_7) treatment. The range of added boron was 0 to 1.20 kg $ha^{-1}yr^{-1}$ and the uptake ranged from 0.11 to 0.35 kg $ha^{-1}yr^{-1}$ in two years of experiments (Table 4.8). The highest negative balance (- 0.22 kg $ha^{-1}yr^{-1}$) was found with soil test based treatment and the lowest negative balance (- 0.11 kg $ha^{-1}yr^{-1}$) was observed with the control. It was observed that the balance was negative with all plots treated with chemical fertilizer alone.

The results revealed that the incorporation of poultry manure, cow dung and oilcake with 75% chemical B fertilizer added large amount of B to soils, which was sufficient to maintain the B balance in soils under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns. Similar results were reported by Jahan *et al.* (2015) and indicated positive B balance in T. aman rice based cropping pattern.

The apparent nutrient balance of all the nutrients like N, P, S, Zn and B were positively higher with chemical fertilizer along with organic manures except K which showed negative balance. The results of this experiment revealed that the external nutrient inputs and nutrient uptake by crops were the key factor for controlling the nutrient balance in Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns. Nutrient balance exercises may serve as instruments to provide indicators for the best nutrient management for sustaining productivity.

Table 4.3. The apparentN balance sheet of Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns as influenced by different treatments in two years of experiments.

Treatment No.	N Added (kg ha^{-1})		N Uptake by crops (kg ha^{-1})		N Balance (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute - T. aman - Mustard cropping pattern						
T_0	0.00	0.00	93.33	90.63	**-93.33**	**-90.63**
T_1	120.26	120.26	182.46	192.86	**-62.20**	**-72.60**
T_2	120.26	120.26	164.47	167.69	**-44.21**	**-47.43**
T_3	334.70	334.70	178.12	189.17	**156.58**	**145.53**
T_4	219.80	219.80	200.67	210.00	**19.13**	**9.80**
T_5	401.00	401.00	248.27	270.66	**152.73**	**130.34**
T_6	291.00	291.00	219.29	211.13	**71.71**	**79.87**
T_7	462.75	462.75	230.66	231.26	**232.09**	**231.49**
T_8	347.85	347.85	215.99	226.11	**131.86**	**121.74**
T_9	529.05	529.05	270.52	283.11	**258.53**	**245.94**
T_{10}	275.00	275.00	198.92	187.65	**76.08**	**87.35**
Jute - T. aman - Lentil cropping pattern						
T_0	0.00	0.00	107.14	101.13	**-107.14**	**-101.13**
T_1	120.26	120.26	209.58	209.73	**-89.32**	**-89.47**
T_2	120.26	120.26	203.58	215.29	**-83.32**	**-95.03**
T_3	334.70	334.70	214.00	226.65	**120.70**	**108.05**
T_4	219.80	219.80	206.95	228.18	**12.85**	**-8.38**
T_5	401.00	401.00	235.42	262.71	**165.58**	**138.29**
T_6	221.00	221.00	208.30	210.00	**12.70**	**11.00**
T_7	410.25	410.25	223.47	241.03	**186.78**	**169.22**
T_8	295.35	295.35	233.68	254.37	**61.67**	**40.98**
T_9	476.55	476.55	240.40	261.67	**236.15**	**214.88**
T_{10}	181.34	181.34	186.55	195.86	**-5.21**	**-14.52**

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 : Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) + recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 : Recom. fertilizer nutrients;
T_7 : Recom. fertilizer nutrients

T_8 : Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});

(75%) + cow dung (5 t ha^{-1});

T_9 : Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and

T_{10} : Soil analysis based treatment

Table 4.4. The apparentP balance sheet of Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns as influenced by different treatments in two years of experiments.

Treatment No.	P Added (kg ha^{-1})		P Uptake by crops (kg ha^{-1})		P Balance (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Jute - T. aman - Mustard cropping pattern						
T_0	0.00	0.00	16.15	15.35	**-16.15**	**-15.35**
T_1	89.64	89.64	29.00	30.21	**60.64**	**59.43**
T_2	89.64	89.64	32.17	32.21	**57.47**	**57.43**
T_3	106.23	106.23	39.45	39.86	**66.78**	**66.37**
T_4	145.53	145.53	38.64	38.85	**106.89**	**106.68**
T_5	111.63	111.63	46.45	48.22	**65.18**	**63.41**
T_6	47.00	47.00	36.55	37.93	**10.45**	**9.07**
T_7	74.25	74.25	39.53	40.93	**34.72**	**33.32**
T_8	113.55	113.55	44.15	42.94	**69.40**	**70.61**
T_9	79.65	79.65	42.25	41.53	**37.40**	**38.12**
T_{10}	57.60	57.60	36.77	34.81	**20.83**	**22.79**
Jute - T. aman - Lentil cropping pattern						
T_0	0.00	0.00	14.24	13.27	**-14.24**	**-13.27**
T_1	89.64	89.64	29.83	27.61	**59.81**	**62.03**
T_2	89.64	89.64	29.55	32.19	**60.09**	**57.45**
T_3	106.23	106.23	33.06	35.70	**73.17**	**70.53**
T_4	145.53	145.53	48.29	44.86	**97.24**	**100.67**
T_5	111.63	111.63	33.58	35.94	**78.05**	**75.69**
T_6	50.00	50.00	29.91	30.24	**20.09**	**19.76**
T_7	76.50	76.50	32.49	35.33	**44.01**	**41.17**
T_8	115.80	115.80	42.44	44.76	**73.36**	**71.04**
T_9	81.90	81.90	34.57	36.03	**47.33**	**45.87**
T_{10}	20.91	20.91	31.07	32.83	**-10.16**	**-11.92**

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;

T_1 : Farmers' practice;

T_2 : Farmers' practice + recom. S&B;

T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});

T_4 : Farmers' practice (75%) + recom. S&B (75%) + recom. poultry manure (3 t ha^{-1});

T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});

T_6 : Recom. fertilizer nutrients;

T_7 : Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});

T_8 : Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 : Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Table 4.5. The apparentK balance sheet of Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns as influenced by different treatments in two years of experiments.

Treatment No.	K Added (kg ha^{-1})		K Uptake by crops (kg ha^{-1})		K Balance (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Jute - T. aman - Mustard cropping pattern						
T_0	0.00	0.00	137.16	126.20	**-137.16**	**-126.20**
T_1	112.05	112.05	287.78	317.71	**-175.73**	**-205.66**
T_2	112.05	112.05	310.92	359.63	**-198.87**	**-247.58**
T_3	240.03	240.03	332.89	374.61	**-92.86**	**-134.58**
T_4	249.63	249.63	362.10	380.62	**-112.47**	**-130.99**
T_5	127.23	127.23	386.65	410.51	**-259.42**	**-283.28**
T_6	76.00	76.00	361.72	295.54	**-285.72**	**-219.54**
T_7	213.00	213.00	395.36	398.02	**-182.36**	**-185.02**
T_8	222.60	222.60	389.37	350.22	**-166.77**	**-127.62**
T_9	100.20	100.20	401.02	410.72	**-300.82**	**-310.52**
T_{10}	62.55	62.55	305.05	288.54	**-242.50**	**-225.99**
Jute - T. aman - Lentil cropping pattern						
T_0	0.00	0.00	112.37	108.20	**-112.37**	**-108.20**
T_1	112.05	112.05	232.68	251.62	**-120.63**	**-139.57**
T_2	112.05	112.05	215.01	244.31	**-102.96**	**-132.26**
T_3	240.03	240.03	276.54	258.97	**-36.51**	**-18.94**
T_4	249.63	249.63	285.41	287.41	**-35.78**	**-37.78**
T_5	127.23	127.23	277.20	271.59	**-149.97**	**-144.36**
T_6	80.00	80.00	243.52	250.04	**-163.52**	**-170.04**
T_7	216.00	216.00	220.57	261.74	**-4.57**	**-45.74**
T_8	225.60	225.60	238.72	345.18	**-13.12**	**-119.58**
T_9	103.20	103.20	271.04	294.65	**-167.84**	**-191.45**
T_{10}	0.00	0.00	239.26	263.38	**-239.26**	**-263.38**

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 : Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) + recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 : Recom. fertilizer nutrients; T_7 : Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 : Recom. fertilizer nutrients T_9 : Recom. fertilizer nutrients T_{10} : Soil analysis based

(75%) + recom. poultry manure (3 t ha^{-1});	(75%) + recom. oilcake (2 t ha^{-1}); and	treatment

Table 4.6. The apparentS balance sheet of Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns as influenced by different treatments in two years of experiments.

Treatment No.	S Added ($kg\ ha^{-1}$)		S Uptake by crops ($kg\ ha^{-1}$)		S Balance ($kg\ ha^{-1}$)	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Jute - T. aman - Mustard cropping pattern						
T_0	0.00	0.00	14.01	13.49	**-14.01**	**-13.49**
T_1	0.00	0.00	27.46	26.81	**-27.46**	**-26.81**
T_2	30.35	30.35	30.10	33.36	**0.25**	**-3.01**
T_3	42.27	42.27	31.41	34.15	**10.86**	**8.12**
T_4	59.67	59.67	30.33	35.82	**29.34**	**23.85**
T_5	69.57	69.57	38.08	46.07	**31.49**	**23.50**
T_6	36.00	36.00	33.82	33.24	**2.18**	**2.76**
T_7	46.50	46.50	37.26	39.36	**9.24**	**7.14**
T_8	63.90	63.90	39.78	39.92	**24.12**	**23.98**
T_9	73.80	73.80	42.80	43.08	**31.00**	**30.72**
T_{10}	0.00	0.00	29.74	30.87	**-29.74**	**-30.87**
Jute - T. aman - Lentil cropping pattern						
T_0	0.00	0.00	11.17	10.70	**-11.17**	**-10.70**
T_1	0.00	0.00	20.36	19.48	**-20.36**	**-19.48**
T_2	32.88	32.88	18.40	22.21	**14.48**	**10.67**
T_3	44.16	44.16	18.45	19.33	**25.71**	**24.83**
T_4	61.56	61.56	21.68	23.65	**39.88**	**37.91**
T_5	71.46	71.46	22.48	23.02	**48.98**	**48.44**
T_6	39.00	39.00	19.55	20.69	**19.45**	**18.31**
T_7	48.75	48.75	20.31	21.25	**28.44**	**27.50**
T_8	66.15	66.15	25.24	25.34	**40.91**	**40.81**
T_9	76.05	76.05	24.20	24.73	**51.85**	**51.32**
T_{10}	0.00	0.00	21.36	20.34	**-21.36**	**-20.34**

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;	T_1 : Farmers' practice;	T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});	T_4 : Farmers' practice (75%) + recom. S&B (75%) + recom. poultry manure (3 t ha^{-1});	T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 : Recom. fertilizer nutrients;	T_7 : Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});	
T_8 : Recom. fertilizer nutrients (75%) + recom. poultry	T_9 : Recom. fertilizer nutrients (75%) + recom. oilcake (2 t	T_{10} : Soil analysis based treatment

manure (3 t ha^{-1}); ha^{-1}); and

Table 4.7. The apparentZn balance sheet of Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns as influenced by different treatments in two years of experiments.

Treatment No.	Zn Added (kg ha^{-1})		Zn Uptake by crops (kg ha^{-1})		Zn Balance (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Jute - T. aman - Mustard cropping pattern						
T_0	0.00	0.00	0.28	0.28	-0.28	-0.28
T_1	6.28	6.28	0.52	0.60	5.76	5.69
T_2	6.86	6.57	0.57	0.62	6.29	5.95
T_3	7.01	7.01	0.58	0.67	6.43	6.35
T_4	8.20	8.20	0.67	0.76	7.53	7.44
T_5	5.54	5.54	0.78	0.88	4.77	4.67
T_6	2.00	2.00	0.63	0.66	1.37	1.35
T_7	3.37	3.37	0.71	0.73	2.67	2.65
T_8	4.56	4.56	0.71	0.80	3.85	3.76
T_9	1.90	1.90	0.76	0.91	1.14	1.00
T_{10}	6.89	6.89	0.62	0.76	6.27	6.13
Jute - T. aman - Lentil cropping pattern						
T_0	0.00	0.00	0.24	0.24	-0.24	-0.24
T_1	6.28	6.28	0.52	0.54	5.76	5.74
T_2	6.86	6.86	0.56	0.63	6.30	6.23
T_3	7.01	7.01	0.53	0.57	6.49	6.45
T_4	8.20	8.20	0.64	0.67	7.57	7.53
T_5	5.54	5.54	0.58	0.64	4.96	4.90
T_6	2.00	2.00	0.55	0.59	1.46	1.41
T_7	3.37	3.37	0.61	0.63	2.76	2.74
T_8	4.56	4.56	0.67	0.73	3.89	3.84
T_9	1.90	1.90	0.66	0.72	1.24	1.19
T_{10}	6.76	6.76	0.53	0.61	6.23	6.15

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 : Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) + recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 : Recom. fertilizer nutrients; T_7 : Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 : Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 : Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Table 4.8. The apparentB balance sheet of Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns as influenced by different treatments in two years of experiments.

Treatment No.	B Added (kg ha^{-1})		B Uptake by crops (kg ha^{-1})		B Balance (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Jute - T. aman - Mustard cropping pattern						
T_0	0.00	0.00	0.14	0.13	-0.14	-0.13
T_1	0.00	0.00	0.18	0.20	-0.18	-0.20
T_2	1.00	1.00	0.22	0.28	0.78	0.72
T_3	1.16	1.16	0.28	0.33	0.88	0.83
T_4	1.20	1.20	0.31	0.39	0.89	0.81
T_5	0.90	0.90	0.27	0.34	0.63	0.56
T_6	1.00	1.00	0.25	0.23	0.76	0.77
T_7	1.16	1.16	0.33	0.32	0.82	0.84
T_8	1.20	1.20	0.40	0.47	0.80	0.73
T_9	0.90	0.90	0.33	0.36	0.57	0.54
T_{10}	0.00	0.00	0.20	0.19	-0.20	-0.19
Jute - T. aman - Lentil cropping pattern						
T_0	0.00	0.00	0.11	0.11	-0.11	-0.11
T_1	0.00	0.00	0.17	0.17	-0.17	-0.17
T_2	1.00	1.00	0.21	0.23	0.79	0.77
T_3	1.16	1.16	0.28	0.31	0.88	0.85
T_4	1.20	1.20	0.33	0.35	0.87	0.85
T_5	0.90	0.90	0.20	0.22	0.70	0.68
T_6	1.00	1.00	0.25	0.26	0.75	0.74
T_7	1.16	1.16	0.22	0.30	0.94	0.86
T_8	1.20	1.20	0.32	0.35	0.88	0.85
T_9	0.90	0.90	0.23	0.24	0.67	0.66
T_{10}	0.00	0.00	0.21	0.22	-0.21	-0.22

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 : Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) + recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 : Recom. fertilizer nutrients;
T_7 : Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 : Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 : Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

4.6. Physical and Chemical Properties of Randomly Collected Soils

Sixteen soil samples were collected at depths of 0 – 15 cm and 15 – 30 cm from 16 different locations of Kashiani upazila to characterize soil fertility level in soils and understand levels of metal pollution of Low Ganges River Floodplain (AEZ-12). The soil samples were collected during the dry period of 2013-14 and analyzed in the laboratory.

4.6.1. Particle-size Distribution and Particle Density of the Soils

Particle-size distribution is one of the most stable soil characteristics, being little modified by cultivation or other practices. Particle-size analysis is mainly used as a basis of soil textural classification. Particle-size distribution, textural classes and particle density of soils collected from 16 different locations are presented in Table 4.9. In topsoil, the clay fraction predominated (28.21 to 76.61%) in the particle-size distribution, which was followed by silt fraction (20.68 to 63.60%) and sand fraction was the lowest (1.54 to 31.321%). In subsoil, the clay (20.45 to 60.54%) and sand (1.25 to 41.81%) fraction decreased while the silt (34.50 to 71.91%) fraction increased with increase in depth. Textural class varied from silty clay loam to clay in both topsoil and subsoil of different samples. The particle density varied from 2.52 and 2.70 g cm^{-3} in topsoil and 2.64 and 2.74 g cm^{-3}in subsoil collected from 16 different locations (Table 4.9).

4.6.2. pH of the Soils

Data presented in Table 4.10indicated that pH values of the surface soil of the investigated areas varied between 6.42 and 7.64 and that of subsurface soils between 6.93 and 8.07 (Table 4.10). In the topsoil, the lowest pH was found with Ghonapara land and the highest with Char Paranpur land. In subsoil, the lowest and highest pH observed with Dhalgram and Fukra land, respectively. The pH of almost all studied topsoils and susoils ranged from slightly acidic to slightly alkaline in reaction, except subsoil of Fukra and Gazaria. In general, the pH values of the topsoils were lower than that of subsoils.

4.6.3. Organic Matter Content of the Soils

An examination of the data presented in Table 4.10 revealed that organic matter contents decreased with the increase in depth in all the soils. The percent of organic matter contents varied from 0.87 to 2.11% in the topsoil and from 0.72 to 1.96% in the subsoil of the sampled soils. The organic matter contents of topsoils were, in general, higher than that of the subsoils. According to the classification of soils on the basis of organic matter content mentioned in fertilizer recommendation guide 2012, the soils of the studied areas were, in general, low to medium in organic matter content (BARC, 2012).

4.6.4. Cation Exchange Capacity (CEC) of the Soils

The CEC of a soil, together with exchangeable bases, provide a measure for evaluating the fertility status of the soil. The data presented in Table 4.10 indicated that the cation exchange capacity decreased with the increase in depth in all soils. The value varied from 10.32 to 32.20 cmol kg^{-1} soil in the topsoil and from 9.52 to 30.41 cmol kg^{-1} soil in the subsoil. The CEC of both topsoil and subsoil ranged between medium and very high (BARC, 2012).

4.6.5. Carbon to Nitrogen Ratio (C:N) of the Soils

The carbon to nitrogen ratio (C:N) of the soils of 16 different locations are presented in Table 4.10. The C:N ratio ranged between 8.00 and 11.96 in the topsoils and 7.40 and 12.15 in the subsoils. The C:N ratio decreased with the increase in depth in most of the soils.

4.6.6. Total Nitrogen Content of the Soils

Nitrogen (N) is the most limiting for crop production in the soils of Bangladesh. The data (Table 4.10) indicated that the percent nitrogen contents were higher in the topsoils compared to the subsoils. The total N contents varied from 0.04 to 0.14% in the topsoil and from 0.03 to 0.10% in the subsoil. Among the sixteen locations, the highest total nitrogen content was found with Choto Bahirbag and Satbaria areas and the lowest value was observed with Gopalpur area. The soil analyses have shown that the level of N in soils was above the critical limit and varied from very low to low (BARC, 2012).

4.6.7. Available Phosphorous Content of the Soils

Phosphorous (P) has great importance for crop production. The available phosphorous in the soil was very limited. The available P contents of the topsoils were generally higher than that of subsoils. The available P content varied from 1.96 to 17.69µg g^{-1} in the topsoils and from 0.81 to 11.58 µg g^{-1} in the subsoils of the sampled areas (Table 4.10). The soil tests showed that available phosphorous content in Bhadulia soil was higher than that of other soils. Most of the soils contained P above the critical level. However, almost all soil samples were in the low to very low range. Only a few soil samples had a medium P levels (BARC, 2012).

4.6.8. Available Sulphur Content of the Soils

An examination of the data presented in Table 4.10 revealed that available sulphur content of majority soils decreased with the increase in depth. The available sulphur content varied from 4.89 to 89.72µg g^{-1} in topsoil and from 1.31 to 66.05µg g^{-1} in subsoil of sixteen areas. According to the fertilizer recommendation guide 2012, the sulphur content in most of the studied soils varied from optimum to very high (BARC, 2012). The available sulphur content was higher in the topsoil compared to the subsoil because of the higher organic matter content of the topsoil.

4.6.9. Available Boron Content of the Soils

The data presented in Table 4.10 indicated that the available boron contents were higher in the topsoils compared to the subsoils. The boron contents varied from 0.86 to 1.89µg g^{-1} in the topsoil and 0.34 to 1.02µg g^{-1} in the subsoil of sampled areas. The B status in the studied topsoils were very high but in subsoils were medium to high (BARC, 2012).

4.6.10. Potassium Content of the Soils

Soil analyses showed that the ammonium acetate extractable K content of the soils varied from 0.126 to 0.479 cmol kg^{-1} soil in topsoils and from 0.081 to 0.397 cmol kg^{-1} soil in subsoils (Table 4.11). In general, the potassium content of the topsoil was higher compared to the subsoil. According to the fertilizer recommendation guide 2012, the K content of topsoils was above the critical level and varied optimum to very high level (BARC, 2012).

4.6.11. Calcium Content of the Soils

Calcium is present in adequate amounts in soils and rarely limits crop production. The highest value of ammonium acetate extractable Ca in topsoil was found to be 8.65 cmol kg^{-1} soil in Paranpur soil and the lowest value was 5.81 cmol kg^{-1} soil in Dhalgram soil. Whereas the Ca content of subsoils varied from 5.94 to 8.74 cmol kg^{-1} soil (Table 4.11).

With a few exceptions, the Ca content of soils increased with increase in depth. The calcium in all the studied soils contained above the critical level and showed optimum to very high level of Ca content (BARC, 2012)

4.6.12. Magnesium Content of the Soils

The data in Table 4.11 indicated that the ammonium acetate extractable Mg contents in most soils were higher in the subsoils compared to the topsoils. The contents of Mg varied from 0.50 to 1.57 cmol kg^{-1} soil in the topsoil and from 0.27 to 1.38 cmol kg^{-1} soilin the subsoil. In general, the Mg content of topsoils is above the critical level and ranged between low to optimum concentration (BARC, 2012).

4.6.13. Micronutrient Contents of the Soils

The results of DTPA extractable micronutrients such as iron, manganese, zinc and copper of soils are shown in Table 4.11. With a few exceptions, the extractable Fe, Mn, Zn and Cu of the soils decreased with increasing depth of soils. The iron content of the topsoil and subsoil varied from 2.50 to 12.00 µg g^{-1} and from 1.14 to 10.62 µg g^{-1}, respectively in the sampled soils. The Mn content of the topsoil varied from 1.49 to 14.62µg g^{-1} and of the subsoil from 0.65 to 7.43µg g^{-1} in the areas under investigation.The Zn content of topsoils varied between 0.24 and 1.03µg g^{-1} and that of the subsoil between 0.09 and0.48µg g^{-1}.The highest zinc content was observed in the topsoil of Char Paranpur area and the lowest was observed in the subsoil of Gazaria areas.The available copper contents of the topsoil and subsoil varied from 0.85 to 5.74µg g^{-1} and 0.50 to 2.82µg g^{-1},respectively. According to the fertilizer recommendation guide 2012, most of the topsoils contained Fe and Zn below the critical level. Whereas the Mn and Cu content in almost all topsoils are above the critical level (BARC, 2012).

4.6.14. Concentration of Lead, Cadmium and Nickel of the Soils

The total concentrations of Pb, Cd and Ni in topsoils collected from sixteen different locations of Kashiani upazila are presented in Table 4.12. Lead contamination in soils has been seriously emphasized in recent years since this metal is very toxic for humans and animals. Lead concentration in sixteen soils of Kashiani area was between 2.75 and 4.13 µg g^{-1}. The average Pb concentration in the soils of the Kashiani area was recorded as 3.47 µg g^{-1}. Lead concentration was highest at Bhulbaria area and lowest at Rajpat area. The total Cd concentration of the sampled topsoils varied from 1.54 to 2.32 $\mu g\ g^{-1}$. The lowest concentration of Cd was found at Char Paranpur area and the highest at Tilchara area. Nickel concentration of the topsoils varied from 6.04 to 8.66 $\mu g\ g^{-1}$. For Ni, the average value was 7.11 $\mu g\ g^{-1}$, with the lowest concentration occurred at Choto Bahirbag area and the highest for Gazaria area. According to the Environmental Protection Agency (2012), the Pb concentrations in all soil samples were lower than that of the typical threshold level (>107 mg kg^{-1}) for agricultural soil. Of the 16 soils studied, none of the soils was contaminated with Cd (>5.2 mg kg^{-1}) and Ni (>100 mg kg^{-1}). The overall scenario of heavy metal concentrations of soils at different locations of Kashiani upazila was below the maximum allowable concentrations of those metals.

Soils of sixteen locations showed considerable variations in nutrient contents. The clay fraction predominated (28.21 to 76.61%) in the topsoil, where the silt (34.50 to 71.91%) fraction was dominant in subsoil. Textural class varied from silty clay loam to clay in both topsoil and subsoil. The particle density ranged between 2.52 and 2.70 $g\ cm^{-3}$in topsoil collected from 16 different locations. The pH of almost all soils ranged from slightly acidic to slightly alkaline in reaction. In general, the organic matter contents of soils were low to medium but CEC of soils ranged between medium and very high. The soil analyses have shown that the level of N, P, S, B, K, Ca, Mg, Mn and Cu in most of the topsoils were above the critical limit, where the topsoils contained Fe and Zn below the critical level. The heavy metal concentrations of soils at different locations of Kashiani upazila were below the maximum allowable concentrations of those metals.

Table 4.9. Percent Sand,Silt,Clay,Textural Class andParticle Density of soils of Kashiani upazila in Gopalganj district.

Sample no	Location	Latitude and Longitude	Sand (%)		Silt (%)		Clay (%)		Textural Class		Particle Density (g cm^{-3})	
			Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
1	Choto Bahirbag	23° 08′ 38.7″N 89° 46′ 59.7″E	4.52	8.66	21.00	47.02	74.49	44.31	Clay	Silty Clay	2.70	2.70
2	Dhalgram	23° 08′ 20.6″N 89° 46′ 44.0″E	9.61	11.82	31.78	53.53	58.61	34.65	Clay	Silty Clay Loam	2.63	2.69
3	Fukra	23° 09′ 02.3″N 89° 46′ 22.3″E	17.08	16.07	33.61	53.88	49.31	30.05	Clay	Silty Clay Loam	2.68	2.71
4	Bhulbaria	23° 09′ 25.2″N 89° 46′ 27.9″E	4.50	2.01	20.68	52.19	74.81	45.80	Clay	Silty Clay	2.66	2.70
5	Gazaira	23° 10′ 03.8″N 89° 47′ 09.9″E	1.54	1.25	30.68	49.18	67.78	49.57	Clay	Silty Clay	2.68	2.72
6	Tarail	23° 10′ 15.5″N 89° 46′ 27.4″E	2.08	3.05	37.07	54.05	60.84	42.90	Clay	Silty Clay	2.69	2.73
7	Gopalpur	23° 10′ 24.3″N 89° 46′ 43.7″E	2.99	4.72	63.60	71.91	33.40	23.37	Silty Clay Loam	Silty Loam	2.52	2.67
8	Paranpur	23° 10′ 50.5″N 89° 46′ 18.4″E	31.32	41.81	40.47	37.73	28.21	20.45	Clay Loam	Loam	2.62	2.71
9	Char Paranpur	23° 10′ 54.7″N 89° 46′ 32.4″E	2.78	4.49	54.20	64.32	43.02	31.19	Silty Loam	Silty Clay Loam	2.69	2.70
10	Tilchara	23° 10′ 49.8″N 89° 46′ 36.7″E	3.80	7.43	24.38	36.22	71.83	56.35	Clay	Clay	2.66	2.69
11	Ghonapara	23° 11′ 10.9″N 89° 46′ 03.0″E	2.33	4.96	21.06	34.50	76.61	60.54	Clay	Clay	2.69	2.73
12	Kamarole	23° 11′ 41.2″N 89° 46′ 29.9″E	4.42	6.89	60.48	68.34	35.10	24.77	Silty Clay Loam	Silty Loam	2.53	2.64
13	Satbaria	23° 12′ 05.9″N 89° 46′ 31.0″E	2.65	3.17	39.72	57.59	57.64	39.24	Clay	Silty Clay	2.64	2.70
14	Bhadulia	23° 11′ 55.9″N 89° 46′ 02.3″E	2.21	2.85	43.33	55.65	54.46	41.50	Silty Clay	Silty Clay	2.67	2.71
15	Ramdya	23° 09′ 30.1″N 89° 48′ 00.9″E	3.12	4.15	44.85	59.67	52.03	36.18	Silty Clay	Silty Clay Loam	2.67	2.74
16	Rajpat	23° 11′ 05.6″N 89° 50′ 04.1″E	5.01	6.10	49.19	61.07	45.80	32.82	Silty Clay	Silty Clay Loam	2.63	2.67

Table 4.10. pH, Organic Matter, CEC, C/N Ratio, TN,Available P,Available S and Available B of soils collected from different spots of Kashiani upazila in Gopalganj district.

Sample no	pH		Organic Matter (%)		CEC (cmol kg^{-1} soil)		C/N Ratio		TN (%)		Available P (µg g^{-1})		Available S (µg g^{-1})		Available B (µg g^{-1})	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
1	6.62	7.66	2.11	1.96	32.20	30.41	8.48	12.15	0.14	0.09	5.79	3.06	43.15	66.05	1.42	0.71
2	6.49	6.93	2.11	1.69	28.07	26.72	9.68	9.56	0.13	0.10	3.06	1.13	34.22	61.87	1.21	0.56
3	7.42	8.07	1.69	1.20	20.64	20.01	10.13	10.86	0.10	0.06	11.92	2.09	12.57	3.31	1.36	0.35
4	6.82	7.13	2.11	1.20	26.63	25.34	9.26	9.96	0.13	0.07	3.54	3.22	89.72	49.99	1.17	0.58
5	7.52	7.91	1.16	1.01	13.21	12.42	10.54	10.77	0.06	0.05	4.34	0.97	14.66	29.33	1.69	0.86
6	7.01	7.63	1.45	0.94	12.38	11.67	10.05	10.31	0.08	0.05	3.86	2.41	4.89	1.31	0.87	0.48
7	7.35	7.78	0.87	0.72	10.32	10.03	11.96	12.12	0.04	0.03	8.37	0.81	9.23	2.54	0.94	0.53
8	7.54	7.72	1.74	1.16	10.73	9.52	10.28	10.80	0.10	0.06	12.65	5.89	23.85	6.82	0.89	0.42
9	7.64	7.79	1.16	0.87	18.55	16.59	11.1	10.8	0.06	0.05	13.11	1.96	23.86	19.31	1.72	0.64
10	7.21	7.66	1.30	1.01	19.81	18.36	11.0	9.7	0.07	0.06	13.56	4.82	11.36	11.35	1.67	0.73
11	6.42	7.47	2.02	1.30	28.69	27.38	9.9	9.0	0.12	0.08	12.85	11.58	17.04	21.58	0.86	0.39
12	7.56	7.59	1.37	1.01	15.04	13.21	8.0	7.4	0.10	0.08	1.96	5.71	32.93	29.53	1.89	0.63
13	7.18	7.32	2.09	1.29	27.04	24.97	8.9	7.4	0.14	0.10	14.54	11.29	40.90	32.95	1.31	0.46
14	7.25	7.48	2.01	1.29	24.56	22.84	9.0	8.1	0.13	0.09	17.69	5.89	36.34	28.39	1.78	1.02
15	7.31	7.51	1.74	1.12	27.45	26.22	10.2	8.1	0.11	0.08	4.93	1.21	7.06	1.54	0.87	0.34
16	7.28	7.47	1.89	1.23	28.28	26.34	9.4	8.5	0.12	0.08	11.36	3.28	18.34	7.91	1.54	0.63

Table 4.11. Ammonium Acetate Extractable (NH_4OAc) K, Na, Ca and Mg and DTPA Extractable Fe, Mn, Zn and Cu of soils collected from different spots of Kashiani upazila in Gopalganj district.

Sample no	NH_4OAc extractable Cations								DTPA Extractable Micronutrients							
	K (cmol kg^{-1} soil)		Na (cmol kg^{-1} soil)		Ca (cmol kg^{-1} soil)		Mg (cmol kg^{-1} soil)		Fe (µg g^{-1})		Mn (µg g^{-1})		Zn (µg g^{-1})		Cu (µg g^{-1})	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
1	0.479	0.397	0.049	0.064	6.78	7.19	1.27	1.26	6.10	2.04	13.74	6.28	0.81	0.35	4.55	2.81
2	0.442	0.361	0.018	0.046	5.81	6.27	0.98	1.01	12.00	10.62	9.66	7.43	0.78	0.41	4.37	2.82
3	0.253	0.172	0.000	0.000	7.49	7.19	0.73	0.75	4.33	2.01	5.16	5.00	0.50	0.23	2.64	1.64
4	0.433	0.370	0.024	0.046	6.53	6.88	1.15	1.18	9.43	7.62	14.62	4.31	0.84	0.39	4.15	1.87
5	0.235	0.172	0.000	0.000	6.57	6.92	0.87	0.94	3.32	2.36	3.69	1.47	0.24	0.09	2.02	1.35
6	0.181	0.117	0.034	0.055	7.42	7.46	0.70	0.76	2.85	2.15	6.79	3.53	0.50	0.28	2.26	1.28
7	0.126	0.090	0.046	0.073	7.17	7.39	0.50	0.58	3.23	2.53	3.01	1.76	0.36	0.33	1.17	0.50
8	0.135	0.081	0.049	0.086	8.65	8.74	0.87	0.87	9.88	8.51	3.28	1.87	0.57	0.26	2.03	1.22
9	0.199	0.135	0.018	0.064	8.01	7.85	0.64	0.70	3.22	2.49	5.96	6.15	1.03	0.44	2.14	1.89
10	0.181	0.126	0.058	0.104	8.45	8.61	0.84	0.93	2.50	2.04	5.66	3.42	0.74	0.48	2.31	1.56
11	0.307	0.253	0.080	0.122	6.05	7.46	0.82	1.28	3.52	1.14	5.57	4.16	0.32	0.27	1.23	2.11
12	0.135	0.081	0.055	0.119	8.05	5.94	0.89	0.27	3.72	2.71	4.03	1.61	0.42	0.18	1.97	0.50
13	0.361	0.307	0.110	0.144	6.80	7.20	1.26	1.29	7.25	5.58	10.70	3.95	0.66	0.36	5.12	1.36
14	0.253	0.217	0.147	0.184	6.38	7.07	1.27	1.29	4.34	3.15	1.49	0.65	0.37	0.14	0.85	0.54
15	0.352	0.298	0.239	0.279	6.57	6.27	1.57	0.98	6.24	2.04	6.19	1.67	0.68	0.27	5.74	1.15
16	0.289	0.253	0.325	0.349	6.61	6.69	1.53	1.38	3.33	2.86	2.04	0.84	0.32	0.26	4.04	1.50

Table 4.12. Total heavy metal concentrations in topsoil samples collected from different spots of Kashiani upazila in Gopalganj district.

Sample no	Total Heavy Metal Concentrations		
	Pb (μg g^{-1})	Cd (μg g^{-1})	Ni (μg g^{-1})
1	3.27	1.91	6.24
2	3.37	2.30	7.06
3	3.74	2.05	6.21
4	4.13	1.88	7.52
5	3.23	1.94	8.66
6	3.86	1.54	6.53
7	4.09	1.66	7.21
8	3.49	1.85	6.69
9	3.24	1.54	6.55
10	3.87	2.32	6.04
11	3.62	1.82	8.48
12	3.12	1.87	6.74
13	3.11	1.62	8.00
14	3.49	1.82	7.43
15	3.12	1.72	6.73
16	2.75	1.77	7.64

CHAPTER 5
SUMMARY

Experiments were conducted in 2013-2014 and 2014-2015 at farmers' field of Paranpur and Tilchara village in Kashiani upazila under Gopalganj district to evaluate the nutritional status of soils due to fertilizer management and intensive cropping with Jute - T.aman - Mustard and Jute - T.aman - Lentil cropping patterns. Jute (*Corchorus olitorius)* cv. BJRI Tossa-2, T.aman rice *(Oryza sativa*) cv. BRRI dhan39, mustard (*Brassica napus*) cv. Rai-5 and lentil (*Lens culinaris*) cv. BARI Masur-2 under these cropping patterns were used as test crops and grown in sequence. Some important physical parameters and chemical properties of soils along with yields, nutrient uptake by crops and nutrient balance of jute, rice, mustard and lentil were studied.

The bulk densities of soils in the 75% of farmers' practice + 75% recommended S & B + cow dungtreated plots decreased considerably in both soils compared to the initial values of 1.33g cm^{-3}in Sara series and 1.46g cm^{-3}in Gopalpur series.The bulk densities varied from 1.17 to1.33 g cm^{-3}in Sara series and 1.20 to 1.46 g cm^{-3}in Gopalpur series. The use of chemical fertilizers andcow dung provided significantly higher hydraulic conductivity, moisture content,organic matter content and CEC in both series soils after two years of experiments. The organic matter contents varied from 1.21 to 1.50% in Sara series and 1.38 to 1.81% in Gopalpur series due to application of different treatments,where the initial values were 1.23% and 1.52% in Sara and Gopalpur series, respectively.

The significantly higher total N contentsof soils (0.118% in Sara series and 0.148% in Gopalpur series) were found with the combined application of 75% of recommended fertilizers and oilcakethan that of the initial values(0.091%in Sara seriesand 0.119%in Gopalpur series) after two years of experiments. The available P contents significantly varied from 9.36 to 16.75 µg g^{-1}in Sara series and 10.14 to 18.95µg g^{-1}in Gopalpur series, where the highest values were observed with 75% of farmers' practice + 75% of recommended S & B + poultry manuretreated plots. The 75% of recommended fertilizers + oilcaketreatment provided significantly higher available S contentsof 35.89µg g^{-1}in Sara series and 41.70 µg g^{-1}in Gopalpur series compared to the initial S contents of 14.18 and 17.47µgg^{-1}, respectively. The ammonium acetate extractable K and Mg contents of soils were significantly higherwith the combined application of 75% of farmers' practice + 75% recommended S & B + cow dung treatment, where theNa and Ca contents were non-significantly influenced due to the application of different treatmentsin both soils.Continuous incorporation of organic manures for a period of two years resulted in accumulation of nutrients in soils to some extent.

The boron content was alsonon-significantlydiffered due to different treatments.Though the variations of micronutrients (Fe, Mn, Zn and Cu) contents in soils were non-significant, the increasing trendsof those nutrients were found with chemical fertilizers + organic manures treatments. The results indicated that the continuous incorporation of organic manures with chemical fertilizers increased the levels of available nutrients in soils compared to the initial nutrients content even under intensive cropping system.

The yields of jute fibre of 4.98 t ha^{-1},jute stick with barkof 14.55 t ha^{-1}, rice grain of 4.57 t ha^{-1}, rice straw of 6.22 t ha^{-1}, mustard grain of 1.45 t ha^{-1} and stover of 4.52 t ha^{-1}in Sara series, and yields of jute fibre of 5.01 t ha^{-1}, jute stick with barkof 14.38 t ha^{-1} and rice grain of 4.54 t ha^{-1}in Gopalpur series soils were significantly higher with 75% of recommended fertilizers + oilcake treatment. But, the treatment composed of 75% of recommended fertilizers +poultry manure provided significantly higher yields of rice straw of 4.52 t ha^{-1}, lentil grain of 1.74 t ha^{-1} and lentil stover of 1.73 t ha^{-1} in soils of Gopalpur series. It is found from the experiments that the combination of 75% of recommended fertilizers and oilcakeismore suitablethan that of other combinations to supply sufficient nutrients for the crops under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns.

With a few exceptions, the nutrient contents in jute, rice, mustardand lentil were significantly influenced due to the application of different treatments in both soils. The highest N, P, K, S, Zn and B contentsin jute stick with bark, rice grain and straw, mustard grain and stover, and lentil grain and stover were found with the combined application of oilcake and chemical fertilizers (75% of farmers' practice or 75% of recommended dose) in Sara and Gopalpur series, which werefollowed by chemical fertilizers +poultry manure and then chemical fertilizers +cow dung treatment. Among the three manures, the oilcake +chemical fertilizers treatment resulted in considerable higher nutrientcontentsin the examined crops compared to other treatments.

The N, P, K, S and B uptake by jute stick with bark; N, P, S and B uptake by rice grain and straw; N, P, K, S, Zn and B uptake by mustard grain and stover; and N, P, K, S, and Zn uptake by lentil grain and stover were significantly influenced due to application of different treatments. The highest N uptake of 88.97 kg ha^{-1} in Sara series and 71.63 kg ha^{-1} in Gopalpur series by jute stick with bark was recorded with the combined application of75% of recommended fertilizersand oilcake. However, the highest P uptake by jute stick with bark were 17.96 kg ha^{-1}in Sara series and 25.56 kg ha^{-1}in Gopalpur series recorded with 75% of farmers' practice + 75% of recommended S & B+oilcake and 75% of farmers' practice + 75% of recommended S & B+ poultry manure, respectively. The S uptake of 19.77 kg ha^{-1}with 75% of recommended fertilizers + cow dung treatment in Sara series and 14.90 kg ha^{-1}with 75% of recommended fertilizers + poultry manure treatment in Gopalpur series were higher than that of other treatments. The B uptake (388.16 g ha^{-1} in Sara series and 319.35 g ha^{-1} in Gopalpur series) by jute stick with bark were highest in the plots wherepoultry manure was applied with chemical fertilizers. The K and Zn uptake was found highest with treatment receiving 75% of recommended fertilizers and cow dung, and soil analysis based treatment, respectively.

The highest N, P, S and B uptake by ricegrain were 60.64 and 67.18 kg ha^{-1}, 8.57 and 8.90 kg ha^{-1}, 4.05 and 4.26 kg ha^{-1},and 8.34 and 9.63 g ha^{-1}, and by rice straw were 49.19 and 41.32 kg ha^{-1}, 9.68 and 8.36 kg ha^{-1}, 6.80 and 4.74 kg ha^{-1},and 10.80and 7.19 g ha^{-1}in Sara and Gopalpur series, respectively, during two years of field experiments. Though the highest N and S uptake by rice grain and straw were observed with chemical fertilizers in combination with oilcake, the highest uptake of P and B were found with 75% of recommended fertilizers and poultry manure treatment.

The highest N uptake of 56.69 and 38.00 kg ha^{-1}, P uptake were 12.99 and 3.42 kg ha^{-1}, K uptake were 13.99 and 93.72 kg ha^{-1}, Zn uptake of 63.53 and 112.94 g ha^{-1} and B uptake of 11.76 and 76.76 g ha^{-1}by mustard grain and stover in Sara and Gopalpur series, respectively wereobserved with 75% of recommended fertilizers + oilcake treatment, which was significantly higher over other treatments.The uptake of N (84.10 kg ha^{-1}), P (6.87 kg ha^{-1}), S (2.26 kg ha^{-1}), Zn (82.73 g ha^{-1}) and B (3.28 g ha^{-1}) by lentil grain werehighest with 75% of recommended fertilizers + poultry manure treatment, while the K uptake (7.59 kg ha^{-1}) was highest with 75% of recommended fertilizers + cow dungtreatment. The maximum N and P uptake by lentil stover was observed with chemical fertilizers and poultry manure treatment. But the 75% of recommended fertilizers + poultry manure treatment yielded the highest K and Zn uptake, and the highest S and B uptake by lentil stover was recorded with 75% of recommended fertilizers + oilcake treatment. The results indicated that the combined application of cow dung, poultry manure and oilcake with chemical fertilizers were considerably higher in case of nutrients uptake by crops than that of chemical fertilizers alone i.e. fertilizers applied by farmers or recommended fertilizers by BARC or soil test based fertilizers.

Soil samples collected from sixteen different locations were analyzed and found that the contents of macro- and micro-nutrient elements in topsoils were above the critical limit except Fe and Zn according to the fertilizer recommendation guide of BARC (2012). Lead, cadmium and nickel concentrations of soils examined in the present study were below the maximum allowable concentrations as recommended by EPA (2012).

In most cases, the yields as well as nutrient concentration and uptake of nutrient by jute, rice, mustard and lentil were significantly influenced due to the application of organic manure (cow dung, poultry manure and oilcake) in Jute - T. aman - Mustard and Jute - T. aman - Lentil production system in Sara and Gopalpur series of Low Ganges River Floodplain Soils (AEZ 12). The N, P, K, S, Zn and B contents and uptake by jute, rice, mustard and lentil were significantly higher withthose treatments composed of chemical fertilizer and organic manure than sole application of chemical fertilizer except some cases. It is clear from the data that the two soilseries responded differently in respect of nutrients content and uptake by crops upon addition of different treatments.The apparent balance of N, P, S, Zn and B were found positivewith the combined application of chemical fertilizers and organic manures, and the negative K balance was also observed in Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns during two years of experiments.The results indicated that the reduction of fertilizer application by 25% and incorporation of organic manures (cow dung, poultry manure and oilcake) increased nutrient balances in both soil series.It can be said from the study that the application of 75% of recommended doseof BARC +2 t ha^{-1}oilcake can be recommended to increase the productivity of crops under introduced Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patternsin place of two crops based cropping patterns as a nutrient management strategy in AEZ 12 of Gopalganj District.

CHAPTER 6
CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

- The nutrient management practices had some significant effect on soils fertility status of both Sara and Gopalpur series. The physical properties specially total porosity, hydraulic conductivity and soil moisture content of Sara and Gopalpur series were significantly influenced by the applied treatments.The treatments had significant influence on soil organic matter and CEC of both Sara and Gopalpur series.
- The major available nutrients (N, P, K and S) were significantly higher under integrated nutrient management compared to purely inorganic nutrient management practices. In addition to that, there was a declining trend of available nutrient under inorganic nutrient management practices. The nutrient management practices significantly increased the organic matter content in soils.
- Continuous application of manures with chemical fertilizers increased the levels of N, P, K, S, Ca and Mg in both soils even under intensive cropping for two years. The source of organic matter i.e. cow dung, poultry manure and oilcake created a reserve of nutrients and enhanced the transformation of nutrients to available form.
- The results indicated that the yields of jute, rice and lentil (except yield of mustard) were significantly superior with the treatments composed of 75% of recommended chemical fertilizers and oilcake, which was followed by 75% of recommended fertilizers + poultry manure and75% of recommended fertilizers + cow dung treatments,but only chemical fertilizers (fertilizers applied by farmers or recommended fertilizers by BARC or soil test based fertilizers) based treatments produced comparatively lower yields. The response of75% of recommended fertilizers+ organic manures was comparatively better in supplying sufficient nutrients for the crops under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patternsthan that of only chemical fertilizers based treatment.
- The results showed that judicious management of nutrients and conservation of soil under intensive cropping may be possible through ensuring continuous supply of organic matter.
- The results indicated that N, P, K, S, Zn, and B uptake by jute, rice, mustard and lentil remarkably increased with the combined application of chemical fertilizers and

organic manures. It was observed that the highest uptake of N, P, K, S, Zn, and B by the crops was noted with the chemical fertilizers + oilcake (T_5 and T_9) and chemical fertilizers + poultry manure (T_4 and T_8)treatments.

- The results of sixteen soils collected from different locations indicated low to medium organic matter contents of soilsbut CEC of soils ranged between medium and very high. The level of N, P, S, B, K, Ca, Mg, Mn and Cuof soils wereabove the critical limit except Fe and Zn; and Pb, Cd and Ni concentrations were found below the allowable limit.

6.2. Recommendations

The results of the experiments suggest the following recommendations:

- Based upon above results it can be recommended that theintegration of oilcake (2 t ha^{-1}) or poultry manure (3 t ha^{-1}) with chemical fertilizers can be practiced for better nutrients availability in soils and thus can maintain the fertility status of different soils, and increase the content and uptake of nutrients by plants.
- The findings of the experiment revealed that 75% of recommended chemical fertilizers of BARC and 2 t ha^{-1}oilcake performed better and could be recommended for the Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns, which was followed by 75% of recommended chemical fertilizers and 3 t ha^{-1}poultry manure. Therefore, 25 percent of chemical fertilizers may be substituted by organic manure which is also necessary for maintaining soil health.
- The overall results indicated that the Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns could be practicedinstead of the existing two crops based cropping patterns in this region under the above recommended nutrient management practices for improving cropping intensity and crop production.

6.3. Future Research

- The effect of chemical fertilizers in combination with other sources of locally available organic manures, not used in this experiment, may be examined for Jute - T. aman - Mustard and Jute - T. aman - Lentil or othercropping sequences by conducting the same type of study.
- Future monitoring of nutrient dynamics under Jute - T. aman - Mustard and Jute - T. aman - Lentil cropping patterns if possible should involve for three years. Prospective studies need to be carried out on the dynamics of micronutrients under different nutrient management practices with different cropping patterns.

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CHAPTER 8: APPENDICES

Appendix 4.1a. Bulk density, particle density, total porosity, hydraulic conductivity and moisture content of soils of Sara series as influenced by nutrient management and intensive cropping during two years period.

Treatment No.	Bulk Density (BD) (g cm^{-3})		Particle Density (PD) (g cm^{-3})		Total Porosity of Soil (%)		Hydraulic Conductivity (Ks) (mm/h)		Soil Moisture Content (%)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Sara Series										
T_0	1.32a	1.31ab	2.67a	2.66a	50.58a	50.84a	12.92cd	13.32bcd	17.35b	17.62bcd
T_1	1.30a	1.31ab	2.66a	2.67a	51.18a	50.82a	12.85cd	12.42cd	17.09b	16.85d
T_2	1.31a	1.31ab	2.67a	2.67a	50.89a	50.94a	13.21bcd	12.75cd	17.19b	17.00cd
T_3	1.19a	1.17b	2.63a	2.64a	54.73a	55.56a	14.56abc	14.62ab	19.41ab	20.40a
T_4	1.20a	1.19ab	2.64a	2.65a	54.58a	54.97a	13.87abcd	13.94abc	18.99ab	19.71ab
T_5	1.24a	1.22ab	2.62a	2.62a	52.71a	53.49a	13.55abcd	13.68abcd	18.69ab	19.19abcd
T_6	1.30a	1.30ab	2.67a	2.66a	51.36a	51.04a	12.53d	12.23d	17.19b	17.06cd
T_7	1.21a	1.19ab	2.63a	2.64a	53.98a	54.87a	15.05a	15.19a	19.91a	20.84a
T_8	1.23a	1.22ab	2.65a	2.65a	53.58a	53.93a	13.88abcd	13.98abc	19.10ab	19.94ab
T_9	1.25a	1.24ab	2.62a	2.62a	52.24a	52.65a	14.90ab	15.11a	18.90ab	19.33abc
T_{10}	1.32a	1.33a	2.66a	2.65a	50.34a	49.73a	12.51d	12.22d	17.09b	17.04cd
CV (%)	**5.95**	**6.20**	**1.76**	**1.54**	**5.43**	**5.90**	**6.73**	**6.49**	**6.57**	**6.77**
LSD $_{0.05}$	**0.127**	**0.132**	**0.079**	**0.069**	**4.819**	**5.255**	**1.553**	**1.492**	**2.033**	**2.137**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.1b. Bulk density, particle density, total porosity, hydraulic conductivity and moisture content of soils of Gopalpur series as influenced by nutrient management and intensive cropping during two years period.

Treatment No.	Bulk Density (BD) ($g\ cm^{-3}$)		Particle Density (PD) ($g\ cm^{-3}$)		Total Porosity of Soil (%)		Hydraulic Conductivity (Ks) (mm/h)		Soil Moisture Content (%)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Gopalpur series										
T_0	1.42a	1.43a	2.67a	2.67a	46.84bc	46.54b	11.72cd	11.32c	21.25a	21.08b
T_1	1.42a	1.43a	2.68a	2.67a	46.97bc	46.48b	11.49d	11.22c	21.28a	21.03b
T_2	1.43a	1.45a	2.68a	2.68a	46.61bc	45.89b	11.83cd	11.37c	21.18a	20.82b
T_3	1.21b	1.20b	2.64a	2.64a	54.14a	54.57a	14.56a	14.82ab	23.29a	24.60a
T_4	1.24b	1.23b	2.64a	2.65a	53.06a	53.58a	13.88ab	14.13ab	22.59a	23.67ab
T_5	1.26b	1.25b	2.62a	2.63a	51.93ab	52.50a	12.53bcd	13.21b	22.10a	23.06ab
T_6	1.43a	1.44a	2.68a	2.68a	46.62bc	46.27b	11.34d	11.26c	21.40a	21.09b
T_7	1.23b	1.22b	2.63a	2.63a	53.26a	53.69a	14.70a	14.87a	23.50a	24.35a
T_8	1.25b	1.24b	2.64a	2.65a	52.63a	53.20a	13.55ab	13.78ab	22.81a	23.64ab
T_9	1.27b	1.27b	2.62a	2.63a	51.50abc	51.73a	13.21abc	13.45ab	22.09a	22.96ab
T_{10}	1.45a	1.46a	2.68a	2.67a	45.88c	45.29b	11.21d	11.32c	21.29a	21.20b
CV (%)	**5.59**	**5.25**	**1.64**	**1.53**	**6.05**	**5.51**	**6.82**	**6.72**	**6.79**	**6.66**
LSD $_{0.05}$	**0.126**	**0.118**	**0.074**	**0.069**	**5.117**	**4.662**	**1.470**	**1.456**	**2.536**	**2.539**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix4.2.Organic Matter (OM), pH, Cation Exchange Capacity (CEC) and Carbon to Nitrogen (C/N) ratioofsoils ofSara and GopalpurSeries as influenced bydifferent treatments and intensive cropping intwo years time.

Treatment No.	OM (%)		pH		CEC (cmol kg^{-1} soil)		C/N Ratio	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Sara Series								
T_0	1.21d	1.20c	7.82a	7.78a	14.58c	14.61b	9.35a	9.55a
T_1	1.24bcd	1.25bc	7.82a	7.89a	14.52c	14.58b	9.18a	9.30a
T_2	1.37abcd	1.35abc	7.79a	7.86a	14.70bc	14.63b	9.78a	9.70a
T_3	1.37abcd	1.50a	7.78a	7.81a	16.44ab	17.27a	8.70a	8.48ab
T_4	1.50a	1.34abc	7.80a	7.84a	16.03abc	16.21ab	7.42a	6.78c
T_5	1.38abc	1.36abc	7.73a	7.73a	15.74abc	16.03ab	7.15a	6.67c
T_6	1.25bcd	1.23bc	7.81a	7.89a	14.49c	14.60b	8.52a	8.66ab
T_7	1.45a	1.39abc	7.82a	7.85a	17.24a	17.71a	8.31a	7.53bc
T_8	1.39ab	1.41ab	7.87a	7.92a	16.64a	16.92a	7.40a	7.05bc
T_9	1.40ab	1.37abc	7.79a	7.84a	16.09abc	16.50ab	7.11a	6.48c
T_{10}	1.26bcd	1.24bc	7.88a	7.93a	14.53c	14.61b	8.74a	8.56ab
CV (%)	**6.30**	**7.59**	**1.62**	**1.33**	**6.25**	**7.47**	**18.65**	**11.31**
LSD $_{0.05}$	**0.144**	**0.171**	**0.214**	**0.177**	**1.646**	**1.997**	**2.632**	**1.545**
GopalpurSeries								
T_0	1.41b	1.40a	7.54a	7.53a	24.18b	24.22b	8.75a	8.82ab
T_1	1.41b	1.38a	7.54a	7.57a	24.21b	24.13b	8.97a	8.78ab
T_2	1.44b	1.40a	7.57a	7.59a	24.16b	24.06b	8.92a	8.77ab
T_3	1.81a	1.66a	7.48a	7.49a	26.44ab	27.16ab	9.94a	8.68ab
T_4	1.70a	1.58a	7.51a	7.54a	25.90ab	26.41ab	8.49a	7.44ab
T_5	1.60ab	1.51a	7.50a	7.51a	25.73ab	26.20ab	7.13a	5.97b
T_6	1.41b	1.39a	7.53a	7.58a	24.86b	24.91b	8.98a	8.68ab
T_7	1.72a	1.67a	7.49a	7.51a	27.78a	28.13a	8.86a	8.06ab
T_8	1.61ab	1.58a	7.52a	7.55a	26.93ab	27.25ab	7.63a	6.70ab
T_9	1.57ab	1.53a	7.52a	7.54a	26.68ab	27.06ab	6.88a	6.07ab
T_{10}	1.45b	1.42a	7.57a	7.61a	24.72b	24.18b	9.16a	8.91a
CV (%)	**8.44**	**11.71**	**1.64**	**1.39**	**5.62**	**6.40**	**20.40**	**18.64**
LSD $_{0.05}$	**0.223**	**0.297**	**0.209**	**0.178**	**2.436**	**2.797**	**2.943**	**2.493**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;

T_1 :Farmers' practice;

T_2 : Farmers' practice + recom. S&B;

T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});

T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});

T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});

T_6 :Recom. fertilizer nutrients;

T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});

T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});

T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and

T_{10} : Soil analysis based treatment

Appendix 4.3a. Total nitrogen (TN), available P, available S and available B content in soils of Sara Series as influenced bynutrient management and intensive cropping during two years period.

Treatment No.	Total Nitrogen (TN) (%)		Available P ($\mu g g^{-1}$)		Available S ($\mu g\ g^{-1}$)		Available B ($\mu g\ g^{-1}$)	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Sara Series								
T_0	0.093abcd	0.089d	9.36c	9.40d	14.37d	13.99e	0.807c	0.796c
T_1	0.079d	0.078d	10.13bc	10.45cd	15.60cd	15.56de	0.817bc	0.837bc
T_2	0.082cd	0.082d	10.22bc	10.48cd	15.43cd	15.91de	0.885abc	0.899abc
T_3	0.102abcd	0.103c	13.33abc	15.50ab	22.39bc	25.16bc	0.944ab	0.965a
T_4	0.110abcd	0.115abc	16.37a	16.75a	24.58ab	28.50ab	0.908abc	0.891abc
T_5	0.116ab	0.119ab	14.24abc	14.69abc	31.11a	35.89a	0.907abc	0.913ab
T_6	0.085bcd	0.082d	10.16bc	10.70cd	15.99cd	16.48cde	0.878abc	0.874abc
T_7	0.104abcd	0.107bc	11.16bc	11.19bcd	19.81bcd	20.59bcde	0.988a	0.941ab
T_8	0.112abc	0.116abc	14.62ab	15.47ab	22.15bcd	23.48bcd	0.944ab	0.929ab
T_9	0.118a	0.123a	12.95abc	13.45abcd	31.89a	35.04a	0.949ab	0.967a
T_{10}	0.086bcd	0.084d	9.53c	10.61cd	15.38cd	15.82de	0.846bc	0.877abc
CV (%)	**16.40**	**7.61**	**20.86**	**19.81**	**19.81**	**21.71**	**6.43**	**7.73**
LSD $_{0.05}$	**0.027**	**0.013**	**4.241**	**4.229**	**6.973**	**8.238**	**0.098**	**0.117**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.3b. Total nitrogen (TN), available P, available S and available B content in soils of GopalpurSeries as influenced by nutrient management and intensive cropping during two years period.

Treatment No.	Total Nitrogen (TN) (%)		Available P ($\mu g\ g^{-1}$)		Available S ($\mu g\ g^{-1}$)		Available B ($\mu g\ g^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Gopalpur Series								
T_0	0.094b	0.092c	10.37c	10.14d	14.29d	14.43d	1.156c	1.110b
T_1	0.093b	0.092c	10.61c	11.28cd	18.44cd	20.55cd	1.345bc	1.187ab
T_2	0.095b	0.094c	10.46c	11.05cd	18.33cd	20.23cd	1.432abc	1.284ab
T_3	0.108ab	0.112bc	14.24abc	15.86abc	23.01bc	31.51b	1.341bc	1.352ab
T_4	0.119ab	0.124ab	17.66a	18.95a	27.08abc	33.55b	1.564ab	1.566ab
T_5	0.133a	0.147a	15.83ab	15.99abc	32.15a	40.70a	1.701a	1.620a
T_6	0.092b	0.093c	10.77c	11.27cd	19.13cd	21.27cd	1.405bc	1.339ab
T_7	0.114ab	0.122ab	12.32bc	13.58bcd	25.99abc	32.15b	1.360bc	1.304ab
T_8	0.125ab	0.138ab	15.22abc	16.66ab	28.23ab	35.32ab	1.535ab	1.507ab
T_9	0.136a	0.148a	13.48abc	14.13abcd	33.59a	41.70a	1.589ab	1.224ab
T_{10}	0.094b	0.094c	10.43c	10.75cd	18.40cd	21.84c	1.324bc	1.244ab
CV (%)	**16.11**	**12.35**	**20.09**	**20.27**	**19.44**	**13.63**	**10.59**	**18.06**
LSD $_{0.05}$	**0.030**	**0.024**	**4.374**	**4.671**	**7.742**	**6.575**	**0.257**	**0.041**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.4a. NH_4OAc extractable K, Na, Ca and Mgin soils of Sara Series as influenced by nutrient management and intensive cropping during two years period.

Treatment No.	NH_4OAc extractable bases							
	K (cmol kg^{-1} soil)		Na (cmol kg^{-1} soil)		Ca (cmol kg^{-1} soil)		Mg (cmol kg^{-1} soil)	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Sara Series								
T_0	0.152d	0.150e	0.055c	0.060b	7.090a	7.070d	0.493c	0.494c
T_1	0.162cd	0.169de	0.062abc	0.073ab	7.233a	7.243bcd	0.477c	0.500c
T_2	0.157cd	0.165de	0.058bc	0.078ab	7.357a	7.513abcd	0.499c	0.533bc
T_3	0.198a	0.227a	0.065abc	0.084ab	7.430a	7.490abcd	0.587ab	0.645ab
T_4	0.181abc	0.211abc	0.075abc	0.090a	7.413a	7.610abcd	0.477c	0.525c
T_5	0.192ab	0.218ab	0.073abc	0.086ab	7.450a	7.517abcd	0.507bc	0.549bc
T_6	0.164bcd	0.172de	0.061abc	0.091a	7.577a	7.907a	0.522abc	0.575bc
T_7	0.193a	0.204abc	0.081ab	0.082ab	7.653a	7.833abc	0.544abc	0.610abc
T_8	0.176abcd	0.190bcd	0.084a	0.092a	7.553a	7.850ab	0.539abc	0.598bc
T_9	0.184abc	0.202abc	0.084a	0.092a	7.540a	7.653abcd	0.605a	0.707a
T_{10}	0.172abcd	0.184cd	0.075abc	0.077ab	7.397a	7.227cd	0.492c	0.557bc
CV (%)	**7.98**	**8.09**	**19.39**	**19.38**	**3.98**	**6.63**	**18.74**	**18.84**
LSD $_{0.05}$	**0.038**	**0.044**	**0.034**	**0.036**	**0.712**	**1.209**	**0.439**	**0.453**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;

T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});

T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});

T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.4b. NH_4OAc extractableK, Na, Ca and Mgin soils of GopalpurSeries as influenced by nutrient management and intensive cropping during two years period.

Treatment No.	NH_4OAc extractable bases							
	K (cmol kg^{-1} soil)		Na(cmol kg^{-1} soil)		Ca(cmol kg^{-1} soil)		Mg (cmol kg^{-1} soil)	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Gopalpur Series								
T_0	0.233d	0.231e	0.091a	0.094a	9.98c	9.88b	1.087c	1.065c
T_1	0.256cd	0.294d	0.099a	0.099a	10.28bc	10.44ab	1.579abc	1.357abc
T_2	0.270bcd	0.298d	0.117a	0.117a	10.78abc	11.12ab	1.566abc	1.576abc
T_3	0.318a	0.387a	0.100a	0.101a	10.53abc	10.84ab	1.169abc	1.419abc
T_4	0.276abc	0.350abc	0.112a	0.121a	10.65abc	11.07ab	1.132bc	1.220bc
T_5	0.298abc	0.368ab	0.112a	0.118a	10.38abc	10.61ab	1.296abc	1.351abc
T_6	0.270bcd	0.287d	0.109a	0.124a	10.96ab	11.32a	1.577abc	1.503abc
T_7	0.305ab	0.351abc	0.094a	0.111a	10.75abc	11.00ab	1.643a	1.868a
T_8	0.281abc	0.326bcd	0.101a	0.115a	11.14a	11.27ab	1.619ab	1.613ab
T_9	0.293abc	0.350abc	0.103a	0.105a	10.64abc	10.79ab	1.471abc	1.455abc
T_{10}	0.278abc	0.304cd	0.110a	0.112a	10.18bc	10.18ab	1.091c	1.198bc
CV (%)	**7.98**	**8.09**	**19.39**	**19.38**	**3.98**	**6.63**	**18.74**	**18.84**
LSD $_{0.05}$	**0.038**	**0.044**	**0.034**	**0.036**	**0.712**	**1.209**	**0.439**	**0.453**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.5a. DTPA extractable Fe, Mn, Zn and Cuin soils of Sara Series as influenced by nutrient management and intensive cropping during two years period.

Treatment No.	DTPA extractable micronutrients							
	Fe (µg g^{-1})		Mn (µg g^{-1})		Zn (µg g^{-1})		Cu (µg g^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Sara Series								
T_0	42.54e	40.64d	26.85b	26.83a	0.734bc	0.709c	2.208b	2.297b
T_1	47.12de	55.88bc	28.43b	27.04a	1.140a	1.166a	2..746ab	2.874ab
T_2	48.30cde	55.51c	40.59a	33.78a	0.935abc	1.034ab	2.585ab	2.834ab
T_3	54.02bcd	66.94abc	28.32b	30.39a	0.895abc	0.980abc	3.342ab	3.581ab
T_4	69.62a	73.95a	35.07ab	28.96a	0.933abc	1.049ab	3.207ab	3.353ab
T_5	58.91bc	71.15a	26.92b	27.48a	0.723bc	0.789bc	2.739ab	2.948ab
T_6	51.98cde	60.33abc	29.90b	25.68a	1.002ab	1.000ab	3.308ab	3.617ab
T_7	55.64bcd	70.01ab	26.82b	26.35a	0.896abc	0.929abc	3.570a	3.872a
T_8	48.86cde	56.73bc	28.01b	27.69a	0.934abc	1.044ab	3.224ab	3.705ab
T_9	64.13ab	67.04abc	27.38b	26.78a	0.703c	0.861bc	2.763ab	2.876ab
T_{10}	53.79bcd	55.43c	33.64ab	32.54a	1.153a	1.183a	2.6634ab	2.841ab
CV (%)	**10.55**	**12.21**	**17.94**	**18.66**	**16.64**	**15.62**	**1997**	**21.25**
LSD $_{0.05}$	**9.659**	**12.659**	**9.168**	**9.009**	**0.257**	**0.258**	**1.004**	**1.243**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.5b. DTPA extractableFe, Mn, Zn and Cuin soils of GopalpurSeries as influenced by nutrient management and intensive cropping during two years period.

Treatment No.	DTPA extractablemicronutrients							
	Fe (μgg^{-1})		Mn(μg g^{-1})		Zn (μg g^{-1})		Cu (μg g^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Gopalpur Series								
T_0	33.99a	33.62a	20.94a	20.07ab	0.955a	0.959a	2.607a	2.528b
T_1	36.17a	38.10a	21.73a	20.95ab	0.974a	1.019a	2.920a	2.991ab
T_2	34.19a	35.23a	25.28a	25.76a	1.027a	1.096a	3.129a	3.152ab
T_3	37.65a	38.94a	21.13a	23.05ab	0.938a	0.899a	3.013a	3.150ab
T_4	36.74a	37.62a	21.40a	22.02ab	0.958a	0.929a	3.201a	3.337ab
T_5	35.59a	37.54a	20.85a	24.65a	0.880a	0.860a	3.655a	3.731a
T_6	35.03a	36.39a	21.95a	15.04b	0.983a	1.050a	3.030a	3.206ab
T_7	36.61a	38.86a	25.06a	25.79a	0.924a	0.891a	3.147a	3.426ab
T_8	38.92a	39.81a	22.89a	25.39a	0.929a	0.959a	3.406a	3.596ab
T_9	40.19a	41.85a	20.93a	23.25ab	0.893a	0.893a	3.600a	3.733a
T_{10}	35.06a	36.13a	20.42a	21.03ab	1.121a	1.162a	2.989a	3.133ab
CV (%)	**10.36**	**13.51**	**19.39**	**19.37**	**18.80**	**18.71**	**19.38**	**14.59**
LSD $_{0.05}$	**6.380**	**8.615**	**7.242**	**7.364**	**0.306**	**0.309**	**1.032**	**0.801**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.6.Yield of crops under Jute - T. aman - Mustard cropping pattern in Sara series as influenced by nutrient management during a period oftwo years.

Treatment No.	Jute Fibre Yield (t ha^{-1})		Jute Stick with Bark Yield (t ha^{-1})		Rice Grain Yield (t ha^{-1})		Rice Straw Yield (t ha^{-1})		Mustard Grain Yield (t ha^{-1})		Mustard Stover Yield (t ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute - T. aman - Mustard Cropping Pattern (Sara Series)												
T_0	2.72h	2.76f	9.61f	9.60f	1.94f	1.98d	3.46f	3.50e	0.53e	0.53e	2.63f	2.51e
T_1	3.88g	3.94e	11.74e	11.85e	3.90e	4.01c	5.46de	5.58d	0.80d	0.78d	3.21e	3.15d
T_2	3.99fg	4.08e	12.05de	12.25de	3.93de	4.08c	5.49cde	5.67bcd	0.79d	0.79d	3.33de	3.31cd
T_3	4.22def	4.27de	12.41cde	12.65cde	4.13de	4.22bc	5.74abcde	5.82abcd	0.94d	0.91d	3.42cde	3.36cd
T_4	4.41bcd	4.48bcd	12.86bcd	13.17bcd	4.35abc	4.41ab	5.96abc	6.02abcd	1.15c	1.12c	3.55bcd	3.48c
T_5	4.58bc	4.64bc	13.75ab	13.95ab	4.42ab	4.49a	6.04ab	6.11ab	1.22bc	1.20bc	3.59bcd	4.52a
T_6	4.01efg	4.09e	12.14cde	12.25de	4.03de	4.10c	5.62bcde	5.68bcd	1.17c	1.14c	3.57bcd	3.49c
T_7	4.31cde	4.43cd	13.18bc	13.54bc	4.17bcd	4.35ab	5.78abcde	5.97abcd	1.28abc	1.25bc	3.63bcd	3.50c
T_8	4.66ab	4.78ab	13.87ab	14.11ab	4.31abc	4.43ab	5.94abcd	6.05abc	1.38ab	1.36ab	3.74ab	3.58c
T_9	4.91a	4.98a	14.27a	14.55a	4.48a	4.57a	6.13a	6.22a	1.45a	1.43a	3.95a	3.90b
T_{10}	4.09efg	4.18de	12.18cde	12.45de	3.94e	4.09c	5.54e	5.75cd	1.35ab	1.33ab	3.68abc	3.61c
CV (%)	**4.12**	**4.28**	**4.54**	**4.26**	**3.63**	**3.23**	**4.54**	**4.24**	**8.74**	**8.72**	**4.52**	**4.44**
LSD $_{0.05}$	**0.290**	**0.307**	**0.964**	**0.920**	**0.244**	**0.223**	**0.427**	**0.406**	**0.162**	**0.159**	**0.266**	**0.269**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.7. Yield of crops under Jute - T. aman - Lentil cropping pattern in Gopalpur series as influenced bydifferent treatments during two years period.

Treatment No.	Jute Fibre Yield (t ha^{-1})		Jute Stick with Bark Yield (t ha^{-1})		Rice Grain Yield (t ha^{-1})		Rice Straw Yield (t ha^{-1})		Lentil Grain Yield (t ha^{-1})		Lentil Stover Yield (t ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute - T. aman - Lentil cropping pattern (Gopalpur Series)												
T_0	2.67g	2.66g	9.40e	9.37e	2.18e	2.16d	2.18d	2.16d	0.94f	0.91f	1.23d	1.19e
T_1	3.70ef	3.77ef	11.35d	11.48d	4.05d	4.16c	4.05c	4.16c	1.28e	1.31e	1.42c	1.47d
T_2	3.62f	3.68f	11.51d	11.76d	4.27abc	4.33abc	4.28abc	4.33abc	1.34de	1.42de	1.47c	1.49cd
T_3	3.80def	3.86def	12.70bc	12.04cd	4.25cd	4.30abc	4.25abc	4.30abc	1.58abc	1.62abc	1.52bc	1.57bcd
T_4	4.02de	4.10cde	11.89cd	12.94bc	4.39abc	4.43ab	4.39ab	4.43ab	1.60abc	1.67abc	1.62ab	1.67ab
T_5	4.67ab	4.73ab	13.59ab	13.86ab	4.39abc	4.48a	4.39ab	4.48ab	1.52bc	1.57bcd	1.59b	1.60abc
T_6	4.02de	4.08cde	12.06cd	11.94d	4.19cd	4.23bc	4.19bc	4.23bc	1.32de	1.36e	1.52bc	1.56bcd
T_7	4.14cd	4.21cd	12.63bc	12.98bc	4.34abc	4.47a	4.34ab	4.47ab	1.64ab	1.70ab	1.63ab	1.67ab
T_8	4.42bc	4.45bc	13.26ab	13.54ab	4.45ab	4.52a	4.45a	4.52a	1.70a	1.74a	1.72a	1.73a
T_9	4.82a	5.01a	14.05a	14.38a	4.48a	4.54a	4.34ab	4.40abc	1.47cd	1.52cd	1.59b	1.61abc
T_{10}	4.02de	4.09cde	12.04cd	12.30cd	4.18cd	4.33abc	4.18bc	4.33abc	1.32de	1.35e	1.46c	1.50cd
CV (%)	**4.90**	**5.21**	**4.52**	**4.26**	**2.78**	**3.04**	**3.03**	**3.23**	**6.18**	**6.11**	**4.26**	**4.51**
LSD $_{0.05}$	**0.331**	**0.358**	**0.935**	**0.895**	**0.194**	**0.215**	**0.210**	**0.228**	**0.149**	**0.152**	**0.110**	**0.118**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.8a. Nitrogen (N), Phosphorus (P) and Potassium (K) content and uptake by Jute Stick with Barkof Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute Stick with Bark(Sara Series)												
T_0	0.53d	0.52c	36.56d	35.23d	0.10e	0.10e	7.12e	6.68f	0.92d	0.83f	63.65g	56.45d
T_1	0.64bcd	0.64abc	50.38bc	49.87cd	0.11e	0.12de	8.59de	9.41ef	1.35bc	1.22bcde	106.25ef	96.13bc
T_2	0.60cd	0.58c	48.21cd	46.91cd	0.14bcde	0.15cd	10.85cd	11.98bcde	1.39bc	1.70a	111.38def	138.15a
T_3	0.87abc	0.86ab	55.19bcd	55.27bcd	0.17ab	0.18ab	14.06b	15.66ab	1.45bc	1.58ab	118.34cdef	131.98a
T_4	0.60cd	0.59bc	50.65cd	51.14bcd	0.13bcde	0.14cd	11.35cd	12.60bcde	1.55ab	1.30bcd	131.08bcde	113.55ab
T_5	0.97ab	0.95a	88.97a	87.71a	0.19a	0.19a	17.39a	17.96a	1.64ab	1.19cde	150.06abc	110.62ab
T_6	0.73bc	0.71abc	74.78abc	74.37abc	0.16abc	0.16abc	13.17bc	13.41bcd	1.73ab	0.96def	141.52abcd	78.54cd
T_7	0.99a	0.95a	86.93a	87.10a	0.15bcd	0.16bcd	13.30bc	14.18bc	1.94a	1.52abc	171.27a	138.17a
T_8	0.64bcd	0.63abc	49.66cd	49.35bcd	0.14bcde	0.14cd	12.94bc	13.44bcd	1.61ab	0.80f	148.35abc	74.86cd
T_9	0.96a	0.93a	80.80ab	79.87ab	0.17ab	0.18ab	10.75cd	11.76cde	1.65ab	1.27bcd	153.77ab	121.61ab
T_{10}	0.64bcd	0.60bc	51.68cd	48.11cd	0.13cde	0.12de	10.62cd	9.70def	1.09cd	0.88ef	88.30fg	70.84cd
CV (%)	**23.34**	**23.66**	**23.80**	**25.92**	**14.06**	**14.09**	**13.95**	**15.97**	**14.26**	**15.99**	**13.84**	**16.74**
LSD $_{0.05}$	**0.297**	**0.293**	**25.570**	**27.526**	**0.033**	**0.035**	**2.794**	**3.363**	**0.358**	**0.326**	**29.482**	**29.139**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.8b. Nitrogen (N), Phosphorus (P) and Potassium (K) content and uptake by Jute Stick with Barkof GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute Stick with Bark(Gopalpur Series)												
T_0	0.49e	0.49de	33.12e	32.67e	0.10d	0.09d	6.89d	6.32d	0.92fg	0.90d	62.07e	60.00e
T_1	0.67abcd	0.65abc	58.79ab	58.15abc	0.15cd	0.12cd	11.11c	9.30cd	1.48abcd	1.07cd	113.18bcd	82.38de
T_2	0.62bcde	0.62abcd	48.86bcd	49.53cd	0.14cd	0.15bc	10.52cd	11.84bc	1.06efg	1.20bcd	82.97de	96.97cd
T_3	0.66abcd	0.66abc	52.89bc	54.03c	0.17bc	0.18b	13.48c	14.74b	1.72ab	1.13bcd	141.89ab	92.90cde
T_4	0.52de	0.52cde	45.00cde	45.97cde	0.24a	0.24a	25.56a	20.84a	1.76a	1.19bcd	149.22a	105.44bcd
T_5	0.79a	0.77a	69.97a	69.75ab	0.14cd	0.15bc	12.32c	13.28bc	1.55abc	1.11bcd	137.94ab	101.18bcd
T_6	0.76abc	0.73ab	60.94ab	57.49bc	0.14cd	0.15bc	11.34c	11.52bc	1.31cdef	1.44abc	104.33cd	113.01bcd
T_7	0.67abcd	0.65abc	56.82bc	56.98bc	0.16cd	0.16bc	13.07c	13.68b	0.80g	1.20bcd	67.40e	104.18bcd
T_8	0.61cde	0.61bcde	54.09bc	55.52bc	0.22b	0.22a	19.11b	20.02a	1.04efg	1.77a	91.23de	160.54a
T_9	0.77ab	0.77a	70.61a	71.63a	0.15cd	0.15bc	13.63c	14.27b	1.34bcde	1.46abc	123.20abc	136.82ab
T_{10}	0.48e	0.47e	38.17de	38.39de	0.15cd	0.16bc	12.21c	12.96bc	1.13defg	1.53ab	90.66de	125.17bc
CV (%)	**12.57**	**12.36**	**12.6**	**14.19**	**17.76**	**14.46**	**17.46**	**16.48**	**17.15**	**17.74**	**17.71**	**15.58**
LSD $_{0.05}$	**0.138**	**0.134**	**11.489**	**12.888**	**0.049**	**0.039**	**4.010**	**3.775**	**0.372**	**0.382**	**32.135**	**27.923**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.9a. Sulphur (S),Zinc (Zn) and Boron (B) content and uptake by Jute Stick with Barkof Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (µg g^{-1})		Zn uptake (g ha^{-1})		B content (µg g^{-1})		B uptake (g ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute Stick with Bark (Sara Series)												
T_0	0.104b	0.101e	7.13d	6.89f	14.65b	13.62b	101.39c	94.09b	15.86d	15.17c	109.63d	104.10d
T_1	0.171a	0.157d	13.37bc	12.42e	18.43ab	23.31ab	145.24abc	185.07a	17.27cd	17.80c	136.43cd	141.92cd
T_2	0.167a	0.175bcd	13.41bc	14.11de	20.83ab	25.36a	166.88abc	205.65a	21.51bcd	26.68abc	172.26bcd	217.80bcd
T_3	0.187a	0.197abc	13.83bc	16.53bcd	16.95ab	21.11ab	138.87bc	177.40ab	27.86abcd	31.78abc	228.40abc	268.05abc
T_4	0.120b	0.177bcd	10.06cd	15.42cde	18.03ab	23.19ab	151.94abc	200.21a	29.31abc	36.58ab	246.93abc	320.71ab
T_5	0.175a	0.181bcd	16.02ab	16.88abcd	19.50ab	25.00a	178.09abc	230.68a	22.15abcd	26.33abc	202.21bcd	243.66abcd
T_6	0.195a	0.187abcd	15.87ab	15.21de	24.10ab	26.42a	197.50ab	216.71a	22.45abcd	21.16bc	184.13bcd	171.98bcd
T_7	0.205a	0.217a	18.23a	19.77a	25.28a	28.70a	222.45a	262.61a	30.87ab	27.96abc	271.34ab	254.81abcd
T_8	0.199a	0.201ab	18.39a	18.71ab	18.28ab	28.06a	168.91abc	260.71a	34.88a	38.83a	322.42a	388.16a
T_9	0.191a	0.192abc	17.87a	18.32abc	17.01ab	20.05ab	157.90abc	193.03a	26.27abcd	28.85abc	248.25abc	278.20abc
T_{10}	0.160a	0.166cd	12.96bc	13.41e	22.37ab	23.85ab	181.96ab	192.87a	16.98cd	16.00c	137.04cd	128.70cd
CV (%)	**13.84**	**9.88**	**14.43**	**10.54**	**24.68**	**24.37**	**24.58**	**25.14**	**28.27**	**32.43**	**29.20**	**34.31**
LSD $_{0.05}$	**0.040**	**0.030**	**3.490**	**2.721**	**8.186**	**9.705**	**0.069**	**0.084**	**11.553**	**14.487**	**0.102**	**0.133**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.9b. Sulphur (S), Zinc (Zn) and Boron (B) content and uptake by Jute Stick with Barkof GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (µg g^{-1})		Zn uptake (g ha^{-1})		B content (µg g^{-1})		B uptake (g ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute Stick with Bark(Gopalpur Series)												
T_0	0.107d	0.102d	7.24f	6.86e	11.77d	11.52c	78.58d	77.94d	15.16c	15.04c	102.53d	100.10c
T_1	0.160ab	0.142ab	12.25bcd	10.94bcd	17.09bc	15.26bc	130.25c	117.35cd	18.19bc	18.44bc	149.55cd	142.81bc
T_2	0.117d	0.123bcd	9.18ef	9.84cd	19.28ab	24.81a	151.56bc	198.13ab	23.64abc	24.77abc	185.13abcd	200.26abc
T_3	0.125cd	0.114cd	10.04de	9.32d	18.18abc	19.02ab	146.16bc	154.95abc	31.61ab	34.07a	255.71abc	280.60a
T_4	0.150abc	0.150ab	13.00abc	13.25ab	23.39a	24.25a	202.35a	213.81a	34.99a	35.83a	302.79a	319.35a
T_5	0.135bcd	0.133abc	12.01bcd	12.12abc	20.26ab	22.93a	120.37c	142.11bc	19.21bc	20.75abc	170.52bcd	188.41abc
T_6	0.135bcd	0.128abcd	10.88cde	10.06cd	13.53cd	15.62bc	163.22abc	179.82ab	27.92abc	29.45abc	225.53abc	232.15abc
T_7	0.137bcd	0.128abcd	11.72bcde	11.27abcd	18.84abc	20.97ab	160.82abc	185.13ab	22.09abc	30.48ab	188.38abcd	268.30ab
T_8	0.169a	0.152a	14.90a	13.78a	20.91ab	22.06ab	185.28ab	199.90ab	32.48ab	34.98a	288.38ab	316.38a
T_9	0.149abc	0.139abc	13.73ab	13.01ab	18.05abc	18.98ab	166.17abc	178.09ab	21.37abc	22.75abc	195.11abcd	211.59abc
T_{10}	0.159ab	0.134abc	12.77abc	11.02bcd	17.68abc	19.14ab	142.24bc	157.37abc	22.11abc	23.22abc	176.80bcd	190.14abc
CV (%)	**11.58**	**10.98**	**12.16**	**12.55**	**16.32**	**19.03**	**16.24**	**19.10**	**30.38**	**30.17**	**30.94**	**31.74**
LSD $_{0.05}$	**0.028**	**0.024**	**2.392**	**2.347**	**4.999**	**6.287**	**0.041**	**0.053**	**12.569**	**13.459**	**0.106**	**0.120**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.10a. Nitrogen (N), Phosphorus (P) and Potassium (K) content and uptake by rice grain of Sara Series as influenced bydifferent treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Rice Grain (Sara Series)												
T_0	0.98a	0.96b	18.96b	18.96b	0.11d	0.12d	2.13e	2.11c	0.19a	0.18a	3.65b	3.63c
T_1	1.18a	1.23ab	45.80a	49.26a	0.16bc	0.15abc	6.15bcd	5.94ab	0.23a	0.21a	8.81a	8.61ab
T_2	1.17a	1.16ab	45.91a	47.22a	0.16abc	0.13cd	6.23bcd	5.20b	0.23a	0.20a	9.03a	8.02ab
T_3	1.10a	1.19ab	45.43a	49.95a	0.18ab	0.17a	7.61ab	7.32a	0.23a	0.23a	9.59a	9.80ab
T_4	1.19a	1.32a	51.69a	58.45a	0.12cd	0.11cd	5.33d	4.96b	0.24a	0.25a	10.36a	11.20ab
T_5	1.17a	1.33a	51.44a	59.72a	0.14bcd	0.13bcd	6.31bcd	5.84ab	0.23a	0.20a	9.97a	9.01ab
T_6	1.31a	1.24ab	52.52a	50.92a	0.13cd	0.12cd	5.01d	4.92b	0.19a	0.17a	7.62a	7.17bc
T_7	1.20a	1.06ab	49.73a	46.17a	0.18ab	0.16ab	7.66ab	7.12a	0.23a	0.24a	9.61a	10.42ab
T_8	1.17a	1.35a	50.42a	59.71a	0.20a	0.17a	8.57a	7.50a	0.26a	0.27a	11.05a	11.96a
T_9	1.15a	1.33a	51.21a	60.64a	0.16abc	0.14abcd	7.28abc	6.42ab	0.22a	0.22a	9.60a	10.04ab
T_{10}	1.27a	1.21ab	49.47a	49.40a	0.15bcd	0.12cd	5.72cd	5.05b	0.21a	0.23a	7.98a	9.52ab
CV (%)	**15.65**	**15.43**	**15.59**	**15.69**	**14.02**	**13.93**	**14.91**	**15.64**	**22.83**	**22.92**	**23.62**	**24.16**
LSD $_{0.05}$	**0.310**	**0.318**	**12.298**	**13.294**	**0.037**	**0.032**	**1.560**	**1.502**	**0.086**	**0.085**	**3.536**	**3.696**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.10b. Nitrogen (N), Phosphorus (P) and Potassium (K) content and uptake by rice grain of GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Rice Grain (Gopalpur Series)												
T_0	0.93ab	0.90c	20.17c	19.57c	0.12b	0.11b	2.54b	2.44b	0.14a	0.14a	3.11b	3.01b
T_1	1.09ab	1.31ab	44.09ab	54.53ab	0.18a	0.17a	7.13a	6.86a	0.20a	0.22a	8.19a	9.25a
T_2	1.14a	1.32ab	48.59a	56.97ab	0.18a	0.17a	7.48a	7.20a	0.22a	0.22a	9.43a	9.59a
T_3	1.02ab	1.28ab	43.28ab	54.98ab	0.18a	0.17a	7.50a	7.16a	0.22a	0.23a	9.47a	9.96a
T_4	0.91b	1.28ab	39.72ab	56.49ab	0.20a	0.18a	8.64a	8.01a	0.23a	0.24a	10.08a	10.57a
T_5	1.05ab	1.50a	46.12ab	67.18a	0.18a	0.17a	8.06a	7.82a	0.22a	0.23a	9.62a	10.08a
T_6	0.93ab	1.16b	38.66b	49.12b	0.18a	0.17a	7.64a	7.15a	0.20a	0.22a	8.48a	9.38a
T_7	1.03ab	1.27ab	44.47ab	57.01ab	0.18a	0.17a	7.68a	7.40a	0.22a	0.23a	9.58a	10.42a
T_8	1.00ab	1.25ab	44.72ab	56.80ab	0.20a	0.19a	8.90a	8.46a	0.24a	0.24a	10.63a	10.90a
T_9	1.07ab	1.31ab	47.58ab	59.29ab	0.19a	0.17a	8.32a	7.71a	0.23a	0.23a	10.02a	10.36a
T_{10}	1.09ab	1.35ab	45.71ab	58.78ab	0.18a	0.17a	7.70a	7.47a	0.23a	0.21a	9.46a	9.23a
CV (%)	**10.76**	**11.66**	**11.02**	**12.71**	**14.04**	**17.13**	**15.06**	**17.86**	**29.32**	**25.26**	**31.44**	**31.60**
LSD $_{0.05}$	**0.186**	**0.250**	**7.858**	**11.555**	**0.042**	**0.048**	**2.611**	**2.932**	**0.164**	**0.143**	**4.747**	**4.998**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;

T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});

T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});

T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.11a. Sulphur (S), Zinc (Zn) and Boron (B) content uptake by rice grain of Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (µg g^{-1})		Zn uptake (g ha^{-1})		B content (µg g^{-1})		B uptake (g ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Grain (Sara Series)												
T_0	0.047e	0.045d	0.92e	0.90d	20.01b	20.24a	38.76b	40.14b	0.82b	0.81cd	1.59d	1.61e
T_1	0.062bcde	0.072bc	2.42cd	2.89bc	28.75ab	29.34a	111.67a	118.31a	0.88b	0.91cd	3.43cd	3.67cde
T_2	0.056cde	0.094a	2.22cd	3.84ab	27.34ab	27.59a	107.22a	112.97a	0.87b	0.58d	4.74abcd	4.87bcde
T_3	0.057cde	0.067c	2.37cd	2.81c	29.25ab	30.55a	120.01a	128.48a	0.93b	0.95bcd	3.83bcd	3.99cde
T_4	0.088a	0.078abc	3.84a	3.43abc	30.34ab	32.13a	132.22a	141.97a	1.31ab	1.35abcd	5.68abc	5.96abc
T_5	0.078ab	0.086abc	3.45ab	3.85ab	31.04ab	33.37a	137.02a	150.25a	1.30ab	1.24abcd	5.74abc	5.58abcd
T_6	0.070abcd	0.081abc	2.84bc	3.30abc	27.74ab	29.42a	111.23a	119.98a	1.76a	1.75ab	7.05ab	7.17abc
T_7	0.051e	0.078abc	2.12cd	3.41abc	30.63ab	31.70a	128.29a	138.63a	1.20ab	1.19abcd	3.64cd	2.50de
T_8	0.063bcde	0.077abc	2.73bcd	3.43abc	31.65ab	32.56a	136.82a	144.74a	1.78a	1.88a	7.69a	8.34a
T_9	0.075abc	0.088ab	3.36ab	4.05a	34.59a	35.43a	154.64a	161.17a	1.51ab	1.62abc	6.79ab	7.44abc
T_{10}	0.053de	0.087abc	2.08d	3.58abc	30.34ab	31.25a	118.37a	128.69a	1.91a	1.84a	7.39a	7.60ab
CV (%)	**15.58**	**13.89**	**15.23**	**16.08**	**24.05**	**27.84**	**24.47**	**29.33**	**28.42**	**33.47**	**30.79**	**34.23**
LSD $_{0.05}$	**0.017**	**0.018**	**0.665**	**0.878**	**11.909**	**14.297**	**0.049**	**0.063**	**0.624**	**0.727**	**0.003**	**0.003**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.11b. Sulphur (S), Zinc (Zn) and Boron (B) content uptake by rice grain of GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (μg g^{-1})		Zn uptake (g ha^{-1})		B content (μg g^{-1})		B uptake (g ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Grain (Gopalpur Series)												
T_0	0.046d	0.045d	1.01d	0.97d	22.76a	21.06a	49.60b	45.08b	0.89c	0.87b	1.93d	1.88c
T_1	0.068abc	0.069c	2.76abc	2.85c	30.96a	32.49a	125.04ab	134.95a	1.64abc	1.58ab	6.65abc	6.58ab
T_2	0.061abcd	0.098a	2.58bc	4.26a	30.86a	31.44a	131.69ab	135.82a	1.50abc	1.43ab	6.41abc	6.17ab
T_3	0.060abcd	0.084abc	2.55bc	3.63abc	31.57a	33.02a	133.80ab	141.73a	1.60abc	1.29b	6.82abc	5.53ab
T_4	0.051c	0.070c	2.23c	3.10bc	34.68a	35.72a	152.57a	157.53a	2.10ab	1.71ab	9.24ab	7.55ab
T_5	0.078a	0.073bc	3.45a	3.30bc	35.54a	38.79a	155.05a	175.09a	1.40abc	1.17b	6.18bc	5.29bc
T_6	0.073ab	0.093ab	3.04abc	3.92ab	32.35a	32.94a	136.41a	139.44a	1.84abc	1.77ab	7.70abc	7.47ab
T_7	0.056bcd	0.073bc	2.44bc	3.27bc	35.70a	28.29a	154.14a	126.59a	1.08c	1.03b	4.70cd	4.60bc
T_8	0.070ab	0.085abc	3.13ab	3.83ab	33.32a	34.86a	148.81a	158.54a	1.57abc	1.27b	6.99abc	5.76ab
T_9	0.064abcd	0.083abc	2.88abc	3.79abc	37.14a	38.61a	164.59a	173.84a	1.35bc	1.13b	6.07bc	5.18bc
T_{10}	0.070ab	0.076bc	2.94abc	3.28bc	31.24a	31.94a	130.69ab	138.49a	2.31a	2.22a	9.63a	9.62a
CV (%)	**15.83**	**14.30**	**16.95**	**15.25**	**33.79**	**31.23**	**33.50**	**31.74**	**31.01**	**34.19**	**30.76**	**35.84**
LSD $_{0.05}$	**0.017**	**0.019**	**0.757**	**0.850**	**18.523**	**17.268**	**0.077**	**0.075**	**0.825**	**0.814**	**0.003**	**0.004**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;

T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});

T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});

T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.12a. Nitrogen (N), Phosphorus (P) and Potassium (K) content and uptake by rice straw of Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Rice Straw (Sara Series)												
T_0	0.51e	0.50c	17.76f	17.47d	0.09f	0.09c	3.23d	3.23d	1.26b	1.22b	43.8b	42.6c
T_1	0.57de	0.59bc	31.02e	33.04c	0.11ef	0.12bc	5.96c	6.70c	2.36a	2.90a	129.4a	161.2ab
T_2	0.59cde	0.62bc	32.63de	35.34bc	0.12cdef	0.12bc	6.47c	6.83bc	2.47a	2.88a	134.5a	164.2ab
T_3	0.67abcd	0.69ab	38.75bcd	40.25abc	0.13abcde	0.13abc	7.59bc	7.40bc	2.55a	3.01a	146.7a	174.9ab
T_4	0.70abc	0.72ab	41.94abc	43.71ab	0.16a	0.15ab	9.68a	9.00ab	2.64a	3.17a	156.9a	190.9ab
T_5	0.77ab	0.81a	46.42a	49.10a	0.16ab	0.16a	9.46ab	9.90a	2.62a	3.07a	157.6a	187.0ab
T_6	0.70abc	0.70ab	39.23bcd	39.81abc	0.11def	0.12bc	6.29c	6.97bc	2.69a	2.62a	151.8a	149.4b
T_7	0.66bcd	0.67ab	38.13cd	40.25abc	0.10ef	0.12bc	5.95c	6.87bc	2.56a	3.06a	147.3a	182.0ab
T_8	0.77ab	0.77a	45.44ab	46.60a	0.15abc	0.13abc	8.75ab	7.87abc	2.65a	3.17a	157.3a	191.5ab
T_9	0.79a	0.79a	48.40a	49.19a	0.15abcd	0.13abc	8.95ab	8.00abc	2.58a	3.15a	157.3a	196.3a
T_{10}	0.60cde	0.63b	32.59de	35.62bc	0.13bcdef	0.11bc	6.80c	6.34c	2.66a	2.68a	144.5a	150.9ab
CV (%)	**9.59**	**10.66**	**10.10**	**12.69**	**14.27**	**15.75**	**14.57**	**16.27**	**13.97**	**13.82**	**13.79**	**14.38**
LSD $_{0.05}$	**0.108**	**0.123**	**6.411**	**8.409**	**0.031**	**0.033**	**1.775**	**1.982**	**0.581**	**0.658**	**32.410**	**39..639**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.12b. Nitrogen (N), Phosphorus (P) and Potassium (K) content and uptake by rice straw of GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Straw (Gopalpur Series)												
T_0	0.63b	0.61b	13.62c	13.32d	0.12b	0.12d	2.69c	2.63e	1.77c	1.72d	38.47c	37.30d
T_1	0.78a	0.77a	31.74b	32.07c	0.15ab	0.13d	5.87b	5.21d	2.92a	3.47a	118.63ab	144.33ab
T_2	0.73ab	0.80a	31.26b	34.43bc	0.14ab	0.15bcd	5.80b	6.51bcd	2.93a	2.79bc	124.93a	120.73bc
T_3	0.82a	0.82a	34.82ab	35.12abc	0.14ab	0.15bcd	5.96b	6.31cd	2.51ab	3.22abc	106.83ab	138.07abc
T_4	0.80a	0.80a	34.89ab	35.41abc	0.17a	0.18ab	7.47ab	8.00ab	2.63ab	3.42ab	115.57ab	153.53a
T_5	0.80a	0.85a	35.39ab	38.00abc	0.15ab	0.16abc	6.71ab	7.27abc	2.58ab	3.20abc	113.77ab	143.87ab
T_6	0.86a	0.86a	35.80ab	36.38abc	0.13ab	0.15cd	5.57b	6.12cd	2.61ab	2.66c	109.20ab	112.13c
T_7	0.85a	0.86a	36.69ab	38.41abc	0.14ab	0.15bcd	5.94b	6.82bc	2.50ab	2.87abc	108.53ab	128.47abc
T_8	0.89a	0.92a	39.70a	41.32a	0.18a	0.18a	7.89a	8.36a	2.73ab	3.48a	121.57a	155.00a
T_9	0.86a	0.88a	37.01ab	38.87ab	0.15ab	0.15bcd	6.46ab	6.66bcd	2.70ab	2.97abc	116.63ab	130.77abc
T_{10}	0.76ab	0.77a	31.82b	33.04bc	0.15ab	0.15bcd	6.10ab	6.59bcd	2.63ab	2.67c	96.33b	114.13bc
CV (%)	**10.58**	**9.61**	**10.80**	**9.87**	**15.25**	**11.52**	**12.99**	**16.60**	**11.24**	**11.56**	**11.49**	**12.77**
LSD $_{0.05}$	**0.143**	**0.132**	**6.033**	**5.720**	**0.038**	**0.030**	**1.410**	**1.698**	**0.488**	**0.577**	**20.710**	**27.096**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.13a. Sulphur (S), Zinc (Zn) and Boron (B) content and uptake by rice straw of Sara Series as influenced by different treatments during two years of experiment.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (µg g^{-1})		Zn uptake (g ha^{-1})		B content (µg g^{-1})		B uptake (g ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Rice Straw (Sara Series)												
T_0	0.063d	0.063d	2.20d	2.20e	27.16d	27.90d	93.88f	98.08d	1.02a	1.06ab	3.50c	3.74c
T_1	0.072cd	0.074cd	3.92c	4.10d	34.02cd	39.07c	185.20e	218.27c	1.12a	1.22ab	6.13bc	6.84abc
T_2	0.076cd	0.086bc	4.18c	4.92bcd	38.04bc	41.31bc	207.95de	234.68c	1.29a	1.43ab	7.01ab	8.15abc
T_3	0.074cd	0.078cd	4.28c	4.55cd	39.98bc	43.18bc	228.68cde	252.02bc	1.20a	1.27ab	6.91abc	7.43abc
T_4	0.081bcd	0.096abc	4.84bc	5.76abc	47.06b	53.03ab	279.69bc	320.52ab	1.48a	1.52ab	8.78ab	9.21ab
T_5	0.107a	0.112a	6.43a	6.80a	57.39a	59.56a	346.08a	363.23a	1.42a	1.42ab	8.51ab	8.62abc
T_6	0.102ab	0.104ab	5.73ab	5.91ab	38.97bc	40.16c	219.49cde	228.39c	1.11a	1.20ab	6.26bc	6.77abc
T_7	0.075cd	0.078cd	4.33c	4.66bcd	41.58bc	42.81bc	241.30bcde	256.01bc	1.09a	0.86b	6.22bc	5.12bc
T_8	0.081bcd	0.092abc	4.85bc	5.56abc	44.52bc	47.84bc	264.71bcd	288.74abc	1.60a	1.79a	9.54a	10.80a
T_9	0.093abc	0.095abc	5.74ab	5.94ab	47.36b	50.46bc	289.74d	314.89ab	1.31a	1.42ab	7.98ab	8.93ab
T_{10}	0.087abc	0.092abc	4.73bc	5.18bcd	40.22bc	44.41bc	218.86cde	250.45bc	1.25a	1.36ab	6.80ab	7.62abc
CV (%)	**14.32**	**13.23**	**14.18**	**13.93**	**13.77**	**14.05**	**13.82**	**15.99**	**24.20**	**31.94**	**23.80**	**33.81**
LSD $_{0.05}$	**0.020**	**0.020**	**1.119**	**1.192**	**9.673**	**10.590**	**0.055**	**0.070**	**0.517**	**0.714**	**0.003**	**0.004**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.13b. Sulphur (S), Zinc (Zn) and Boron (B) content and uptake by rice straw of GopalpurSeries as influenced by different treatments during two years of experiment.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (μg g^{-1})		Zn uptake (g ha^{-1})		B content (μg g^{-1})		B uptake (g ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Straw (Gopalpur Series)												
T_0	0.068d	0.066d	1.48e	1.42e	31.67b	32.35c	68.64c	69.89c	1.03a	1.05a	2.23c	2.25b
T_1	0.081abc	0.083bc	3.27bcd	3.45cd	42.31ab	44.91abc	171.85ab	187.10ab	1.24a	1.32a	5.02ab	5.49ab
T_2	0.082abc	0.110a	3.49abc	4.74a	43.58ab	44.86abc	186.34ab	194.38ab	1.04a	1.12a	4.42bc	4.85ab
T_3	0.073bcd	0.080bc	3.10bcd	3.45cd	35.09ab	37.83bc	148.96b	162.60b	1.15a	1.21a	4.88ab	5.19ab
T_4	0.076bcd	0.090bc	3.33bc	3.99bcd	39.12ab	41.71abc	171.82ab	184.79ab	1.53a	1.58a	6.73a	6.96a
T_5	0.084abc	0.091bc	3.68ab	4.08b	42.67ab	43.97abc	188.17ab	197.80ab	1.35a	1.46a	5.88ab	6.58a
T_6	0.065d	0.086bc	2.72d	3.63bcd	33.62b	36.46bc	140.25b	154.39b	1.33a	1.43a	5.57ab	6.01a
T_7	0.071cd	0.076cd	3.08cd	3.41d	44.62ab	47.15ab	193.19ab	210.53ab	1.11a	1.12a	4.82ab	5.01ab
T_8	0.083abc	0.089bc	3.69ab	4.04bc	47.86a	52.49a	213.55a	236.80a	1.41a	1.58a	6.31ab	7.19a
T_9	0.092a	0.093b	4.00a	4.10b	48.85a	53.80a	211.15a	235.66a	1.33a	1.38a	5.73ab	6.10a
T_{10}	0.084ab	0.087bc	3.52abc	3.75bcd	37.68ab	48.87ab	157.86ab	210.68ab	1.21a	1.29a	5.05ab	5.57ab
CV (%)	**8.72**	**8.84**	**9.80**	**9.03**	**17.40**	**17.00**	**17.73**	**16.75**	**22.76**	**30.48**	**22.03**	**32.62**
LSD $_{0.05}$	**0.012**	**0.013**	**0.533**	**0.557**	**11.978**	**12.678**	**0.051**	**0.053**	**0.481**	**0.681**	**0.002**	**0.003**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.14. Nitrogen (N), Phosphorus (P)and Potassium (K) content and uptake bymustard grainof Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Mustard Grain (Sara Series)												
T_0	1.76e	1.70f	9.33e	9.05g	0.58b	0.52d	3.06e	2.80e	0.54e	0.52d	2.88f	2.77f
T_1	2.21de	2.53e	17.68de	22.04f	0.81a	0.85bc	6.44d	6.71d	0.72d	0.71c	5.76e	5.58e
T_2	2.80bc	2.70de	22.14d	23.54f	0.83a	0.82c	6.57d	6.39d	0.76cd	0.73bc	5.97e	5.66e
T_3	2.51cd	2.81de	23.82d	29.79ef	0.85a	0.89ab	8.01cd	8.10d	0.82bcd	0.81abc	7.77de	7.40de
T_4	3.40ab	3.03cde	39.16bc	40.10cd	0.87a	0.91ab	9.91b	10.21bc	0.85abc	0.83abc	9.72cd	9.30cd
T_5	3.43a	3.24bcd	41.89abc	43.55bc	0.87a	0.93a	10.60ab	11.10abc	0.86abc	0.85a	10.54bc	10.16bc
T_6	3.11ab	3.54abc	36.32c	30.78ef	0.83a	0.88abc	9.76bc	10.05c	0.80bcd	0.81abc	9.46cd	9.28cd
T_7	3.21ab	3.56abc	41.12bc	44.78bc	0.79a	0.87abc	10.12b	10.90bc	0.86abc	0.84ab	11.01bc	10.51bc
T_8	3.59a	3.66ab	49.60ab	50.90ab	0.80a	0.89ab	11.06ab	12.08ab	0.90ab	0.86a	12.41ab	11.70ab
T_9	3.58a	3.98a	52.11a	56.69a	0.83a	0.91ab	12.08a	12.99a	0.96a	0.92a	13.99a	13.10a
T_{10}	3.20ab	3.24bcd	43.04abc	33.68de	0.82a	0.87abc	11.10ab	11.65abc	0.86abc	0.82abc	11.55bc	10.94bc
CV (%)	**10.70**	**9.79**	**16.62**	**14.92**	**5.08**	**3.91**	**11.65**	**11.23**	**7.65**	**7.75**	**14.08**	**12.47**
LSD $_{0.05}$	**0.540**	**0.520**	**9.629**	**8.840**	**0.069**	**0.056**	**1.771**	**1.781**	**0.105**	**0.104**	**2.190**	**1.850**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.15. Sulphur (S), Zinc (Zn) and Boron (B) content and uptake by mustard grain of Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (µg g^{-1})		Zn uptake (g ha^{-1})		B content (µg g^{-1})		B uptake (g ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Mustard Grain (Sara Series)												
T_0	0.08f	0.09d	0.45e	0.46e	21.64d	24.70c	11.47f	13.17e	4.16a	4.14cd	2.20c	2.21d
T_1	0.17c	0.13bc	1.29d	1.03d	31.56c	32.70bc	25.25e	25.50de	7.26a	8.76ab	5.72bc	7.03abc
T_2	0.28a	0.22a	1.37d	1.72bc	33.12bc	34.09b	25.98e	26.52de	7.57a	6.62abcd	6.01bc	5.16bcd
T_3	0.15cde	0.13bc	1.39cd	1.20cd	34.06bc	34.94ab	32.37de	31.61cd	7.46a	8.48ab	7.21abc	7.89abc
T_4	0.15cd	0.14b	1.54cd	1.59bc	36.61abc	38.27ab	42.22cd	43.47c	7.57a	9.71a	8.85ab	11.08a
T_5	0.22b	0.21a	1.58bcd	2.54a	39.66ab	41.37ab	47.99bc	49.92b	7.85a	7.23abcd	9.67ab	8.80abc
T_6	0.11ef	0.10cd	1.76bcd	1.18cd	35.29bc	37.03ab	41.26cd	42.58bc	7.09a	6.55abcd	8.13ab	7.43abc
T_7	0.12def	0.12bcd	1.79bcd	1.45bcd	36.87abc	36.91ab	47.35bc	46.09b	5.93a	6.13abcd	7.47ab	7.75bc
T_8	0.13de	0.12bc	2.01bc	1.67bc	38.60ab	39.61ab	53.40ab	53.68ab	7.82a	7.52abc	10.87ab	10.18ab
T_9	0.14cde	0.13bc	2.18ab	1.88b	42.34a	44.30a	61.32a	63.53a	8.02a	5.52bcd	11.74a	7.79abc
T_{10}	0.11def	0.11bcd	2.23a	1.46bcd	33.06bc	34.40b	44.84bc	45.96b	7.27a	3.64d	9.68ab	4.77cd
CV (%)	**14.73**	**14.12**	**20.22**	**19.22**	**9.99**	**13.85**	**14.57**	**19.07**	**31.21**	**29.06**	**35.90**	**33.26**
$LSD_{0.05}$	**0.038**	**0.033**	**0.560**	**0.479**	**5.886**	**8.495**	**0.010**	**0.013**	**3.747**	**3.324**	**0.005**	**0.004**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.16. Nitrogen (N),Phosphorus (P)and Potassium (K) content and uptake bymustard stoverof Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Mustard Stover (Sara Series)												
T_0	0.41c	0.39cd	10.72f	9.92d	0.023e	0.021d	0.60g	0.53f	0.88c	0.83d	23.18d	20.75f
T_1	0.42c	0.43bcd	13.58ef	13.65bcd	0.058d	0.046bc	1.86f	1.45de	1.17b	1.47bc	37.56c	46.19de
T_2	0.47bc	0.44bcd	15.58cdef	14.68bcd	0.061cd	0.054bc	2.05ef	1.81cde	1.509a	1.32c	50.04b	43.60e
T_3	0.44bc	0.41bcd	14.93def	13.91bcd	0.064cd	0.041c	2.19def	1.38e	1.48a	1.50bc	50.49b	50.53cde
T_4	0.49bc	0.48bcd	17.23bcde	16.60bcd	0.067bcd	0.059ab	2.37cde	2.08bcd	1.52a	1.60ab	54.04b	55.67cd
T_5	0.55bc	0.56bc	19.55bcd	30.58a	0.075ab	0.062ab	2.69bc	3.42a	1.63a	1.70ab	58.48ab	93.72a
T_6	0.46bc	0.44bcd	16.44cde	15.25bcd	0.065bcd	0.074a	2.32cde	2.58b	1.44a	1.46bc	51.32b	51.15cde
T_7	0.41c	0.37d	14.75def	12.96cd	0.069bc	0.053bc	2.50bcde	1.86cde	1.55a	1.62ab	56.17b	56.96cd
T_8	0.56bc	0.55bc	20.87bc	19.55bc	0.076ab	0.057b	2.83ab	2.05bcd	1.62a	1.68ab	60.26ab	60.20bc
T_9	0.97a	0.94a	38.00a	36.72a	0.081a	0.060ab	3.19a	2.35bc	1.68a	1.79a	66.36a	69.67b
T_{10}	0.60b	0.58b	22.14b	20.84b	0.069bc	0.057b	2.54bcd	2.06bcd	1.43a	1.28c	52.72b	46.34de
CV (%)	**17.04**	**17.73**	**15.32**	**20.16**	**9.14**	**15.85**	**10.67**	**16.95**	**8.90**	**9.04**	**10.70**	**10.69**
LSD $_{0.05}$	**0.151**	**0.152**	**4.808**	**6.351**	**0.010**	**0.014**	**0.413**	**0.562**	**0.218**	**0.226**	**9.235**	**9.786**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.17. Sulphur (S), Zinc (Zn) and Boron (B) content and uptake by mustard stoverof Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (µg g^{-1})		Zn uptake (g ha^{-1})		B content (µg g^{-1})		B uptake (g ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Mustard Stover (Sara Series)												
T_0	0.13d	0.12e	3.32f	3.05g	13.19c	12.37d	34.63d	31.18d	7.28a	7.31a	18.99b	18.55c
T_1	0.20c	0.20d	6.46e	6.37f	17.62b	17.59c	56.72c	55.27c	9.17a	11.08a	29.68ab	34.59bc
T_2	0.27b	0.26bc	8.91cd	8.77cde	18.53b	18.64c	61.45c	61.85c	10.04a	12.01a	33.22ab	40.05bc
T_3	0.28b	0.27bc	9.54cd	9.06cde	17.27b	18.55c	59.07c	62.27c	10.70a	13.06a	36.69ab	43.61bc
T_4	0.28b	0.28ab	10.06bc	9.62cd	17.62b	19.04c	62.47c	66.29c	11.63a	13.06a	41.12ab	45.19b
T_5	0.30ab	0.29ab	10.61bc	16.00a	19.29b	20.51bc	69.17c	112.94a	11.71a	13.99a	41.87ab	76.76a
T_6	0.21c	0.22cd	7.62de	7.64def	17.54b	16.65c	62.81c	58.29c	10.93a	10.90a	39.45ab	37.79bc
T_7	0.30ab	0.29ab	10.78bc	10.07c	17.88b	19.63bc	64.58c	68.60c	12.55a	13.09a	44.98ab	46.06b
T_8	0.32ab	0.30ab	11.80ab	10.55c	23.26a	23.43ab	86.98b	83.72b	12.94a	14.08a	48.54a	50.67b
T_9	0.35a	0.33a	13.65a	12.89b	25.19a	27.19a	99.10a	106.11a	14.33a	14.58a	57.24a	56.47ab
T_{10}	0.21c	0.20d	7.74de	7.24ef	15.93bc	18.89c	58.55c	68.09c	11.59a	11.97a	42.46ab	43.45bc
CV (%)	**11.90**	**11.79**	**12.27**	**12.34**	**10.84**	**11.71**	**10.13**	**12.22**	**33.69**	**30.50**	**34.92**	**30.72**
LSD $_{0.05}$	**0.052**	**0.050**	**1.899**	**1.924**	**3.391**	**3.829**	**0.011**	**0.015**	**6.372**	**6.346**	**0.023**	**0.023**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.18. Nitrogen (N), Phosphorus (P) andPotassium (K) content and uptake bylentil grainof GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Lentil Grain (Gopalpur Series)												
T_0	3.31b	3.05e	31.42e	27.54e	0.18c	0.17c	1.68d	1.50e	0.36b	0.33c	3.36e	2.93e
T_1	4.49a	3.96cd	57.38d	52.08d	0.37a	0.38ab	4.64abc	4.94cd	0.40a	0.41b	5.14d	5.37d
T_2	4.48a	4.30bc	60.11cd	60.82c	0.37a	0.39ab	4.98abc	5.51bc	0.43a	0.43ab	5.70cd	6.02cd
T_3	4.35a	4.30bc	68.90bc	69.56b	0.32ab	0.39ab	4.98abc	6.27ab	0.43a	0.45ab	6.79ab	7.19a
T_4	4.29a	4.56ab	68.80bc	75.93b	0.33ab	0.39ab	5.32ab	6.49ab	0.41a	0.42ab	6.61ab	6.99ab
T_5	4.35a	4.58ab	66.16bc	71.60b	0.34ab	0.40ab	5.20ab	6.25ab	0.40a	0.41ab	6.08bc	6.46bc
T_6	4.54a	3.98cd	60.07cd	53.94d	0.33ab	0.33b	4.32bc	4.44d	0.40a	0.41b	5.35cd	5.53d
T_7	4.24a	4.33bc	69.64ab	73.42b	0.30b	0.39ab	4.95abc	6.57ab	0.43a	0.45a	7.08a	7.59a
T_8	4.56a	4.83a	77.50a	84.10a	0.33ab	0.40ab	5.61a	6.87a	0.43a	0.43ab	7.22a	7.43a
T_9	4.59a	4.92a	67.53bc	74.88b	0.36ab	0.42a	5.24ab	6.40ab	0.41a	0.41ab	6.08bc	6.25c
T_{10}	4.36a	3.78d	55.93d	50.83d	0.32ab	0.35ab	4.07c	4.65cd	0.41a	0.41b	5.21d	5.47d
CV (%)	**4.36**	**5.20**	**7.49**	**5.73**	**9.97**	**10.47**	**11.30**	**10.57**	**4.75**	**4.94**	**7.10**	**6.03**
LSD $_{0.05}$	**0.320**	**0.373**	**7.882**	**6.132**	**0.054**	**0.064**	**0.887**	**0.975**	**0.033**	**0.034**	**0.706**	**0.625**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.19. Sulphur (S), Zinc (Zn) and Boron (B) content and uptake by lentil grain of GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (µg g^{-1})		Zn uptake (g ha^{-1})		B content (µg g^{-1})		B uptake (g ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Lentil Grain (Gopalpur Series)												
T_0	0.07e	0.07e	0.66d	0.65d	32.18b	34.31b	30.28b	30.97b	0.87c	0.89b	0.83c	0.79b
T_1	0.10d	0.11d	1.28c	1.41c	48.26a	49.11a	61.46a	64.95a	1.30abc	1.35ab	1.67bc	1.79ab
T_2	0.14a	0.14ab	1.89a	2.01a	49.86a	51.02a	67.11a	72.36a	1.81ab	1.93a	2.44ab	2.71a
T_3	0.12bcd	0.12cd	1.86ab	1.91ab	43.92a	46.19a	69.38a	74.39a	1.39abc	1.40ab	2.17ab	2.24ab
T_4	0.12abcd	0.12bcd	1.92a	2.07a	44.93a	47.90a	71.76a	79.63a	1.45abc	1.51ab	2.32ab	2.50ab
T_5	0.13ab	0.13abc	1.99a	2.11a	50.72a	52.12a	77.45a	81.29a	1.65abc	1.74a	2.53ab	2.71a
T_6	0.12bcd	0.12cd	1.52bc	1.59bc	53.37a	53.70a	70.82a	72.55a	1.34abc	1.53ab	1.75bc	2.06ab
T_7	0.11bcd	0.12cd	1.87ab	1.99a	43.44a	44.97ab	71.67a	75.96a	1.03bc	1.39ab	1.70bc	2.33ab
T_8	0.13abc	0.13abc	2.12a	2.28a	46.85a	47.67a	79.27a	82.73a	1.85ab	1.90a	3.11a	3.28a
T_9	0.14a	0.15a	2.08a	2.26a	50.54a	53.54a	74.33a	81.67a	1.97a	2.06a	2.86a	3.11a
T_{10}	0.11cd	0.11d	1.34c	1.45c	49.67a	50.25a	63.45a	67.76a	1.35abc	1.49ab	1.72bc	2.00ab
CV (%)	**10.18**	**9.92**	**11.67**	**12.03**	**13.67**	**13.79**	**14.51**	**13.76**	**31.91**	**28.28**	**30.27**	**30.23**
LSD $_{0.05}$	**0.020**	**0.020**	**0.333**	**0.365**	**10.81**	**11.27**	**0.016**	**0.017**	**0.785**	**0.748**	**0.001**	**0.001**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.20. Nitrogen (N), Phosphorus (P) andPotassium (K) content and uptake by lentil stoverofGopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	N content (%)		N uptake (kg ha^{-1})		P content (%)		P uptake (kg ha^{-1})		K content (%)		K uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Lentil Stover (Gopalpur Series)												
T_0	0.71d	0.68e	8.81e	8.03d	0.035c	0.032d	0.43d	0.38e	0.44d	0.42e	5.37c	4.96d
T_1	1.24a	0.91abcd	17.58abc	12.90c	0.076a	0.088a	1.08ab	1.30abc	0.69a	0.70ab	9.85ab	10.29abc
T_2	1.00bc	0.82d	14.76bcd	13.54bc	0.052bc	0.076ab	0.77c	1.13bcd	0.69ab	0.74a	10.08ab	11.00ab
T_3	0.93bc	0.86cd	14.11cd	12.96c	0.075a	0.078ab	1.14ab	1.22abc	0.65abc	0.69bc	9.86ab	10.84ab
T_4	1.14ab	0.88bcd	18.54a	14.38abc	0.080a	0.091a	1.31a	1.52a	0.64bc	0.65bcd	10.30a	10.89ab
T_5	1.12ab	1.01abc	17.78ab	16.18ab	0.081a	0.083ab	1.28a	1.32ab	0.62c	0.62d	9.79ab	10.00bc
T_6	0.84cd	0.84d	12.83d	13.07c	0.069ab	0.065bc	1.04abc	1.00bcd	0.65abc	0.64cd	9.78ab	9.99bc
T_7	0.97bc	0.91abcd	15.85abcd	15.21abc	0.052bc	0.051cd	0.85bc	0.86d	0.67abc	0.66bcd	10.88a	11.08ab
T_8	1.03abc	0.96abcd	17.67abc	16.63a	0.054b	0.061bc	0.93bc	1.06bcd	0.64abc	0.65bcd	11.01a	11.31a
T_9	1.11ab	1.05a	17.67abc	17.00a	0.057b	0.062bc	0.91bc	1.00cd	0.64bc	0.65cd	10.17ab	10.44abc
T_{10}	1.05abc	1.02ab	14.92bcd	14.82abc	0.070ab	0.080ab	0.99bc	1.16bcd	0.64bc	0.64cd	9.01b	9.38c
CV (%)	**11.43**	**8.78**	**12.07**	**10.20**	**15.36**	**17.14**	**15.85**	**15.62**	**4.53**	**4.25**	**6.73**	**6.41**
LSD $_{0.05}$	**0.196**	**0.134**	**3.170**	**2.430**	**0.017**	**0.020**	**0.262**	**0.287**	**0.048**	**0.046**	**1.099**	**1.087**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.21. Sulphur (S), Zinc (Zn) and Boron (B) content and uptake by lentil stoverof GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	S content (%)		S uptake (kg ha^{-1})		Zn content (µg g^{-1})		Zn uptake (g ha^{-1})		B content (µg g^{-1})		B uptake (g ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Lentil Stover (Gopalpur Series)												
T_0	0.064cd	0.067bcd	0.79c	0.80c	11.62e	12.87d	14.37c	15.38f	4.23b	4.24b	5.22b	5.10b
T_1	0.055d	0.057d	0.79c	0.84c	22.4abcd	23.01abc	31.94ab	33.82cde	9.07ab	9.07ab	12.95ab	13.27a
T_2	0.086ab	0.092ab	1.26a	1.36ab	17.91de	18.28cd	26.31b	27.09e	9.13ab	9.11a	13.52a	13.47a
T_3	0.059d	0.065cd	0.90bc	1.02bc	18.12cde	19.79bcd	27.60b	31.07de	6.96ab	6.99ab	10.64ab	10.95ab
T_4	0.073bcd	0.075abcd	1.19ab	1.24ab	21.88abcd	22.33abc	35.64ab	37.20abcde	7.40ab	7.41ab	12.12ab	12.34ab
T_5	0.086ab	0.088ab	1.35a	1.41a	26.03ab	27.85ab	41.15a	44.55abc	7.98ab	8.03ab	12.58ab	12.81a
T_6	0.093ab	0.095a	1.40a	1.50a	23.23abcd	26.26ab	35.29ab	40.75abcd	6.81ab	6.87ab	10.36ab	10.67ab
T_7	0.073bcd	0.078abcd	1.20ab	1.31ab	19.55bcd	21.07abc	32.04ab	35.13bcde	8.60ab	8.76ab	14.13a	14.72a
T_8	0.081abc	0.081abc	1.40a	1.41a	25.39abc	27.02ab	43.44a	46.77a	8.74ab	8.87ab	14.92a	15.32a
T_9	0.095a	0.097a	1.51a	1.57a	27.35a	28.48a	43.70a	45.77ab	10.74a	10.71a	16.96a	17.45a
T_{10}	0.056d	0.057d	0.79c	0.84c	26.15ab	27.38ab	37.01ab	39.99abcd	9.19ab	9.23a	12.99ab	13.24a
CV (%)	**14.72**	**15.59**	**16.27**	**16.23**	**17.58**	**18.06**	**19.39**	**16.06**	**33.98**	**30.69**	**34.49**	**32.01**
LSD $_{0.05}$	**0.019**	**0.020**	**0.315**	**0.332**	**6.485**	**7.070**	**0.011**	**0.010**	**4.648**	**4.219**	**0.007**	**0.007**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.22a. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by Jute Stick with Barkof Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (µg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Jute Stick with Bark(Sara Series)												
T_0	0.692b	0.684e	47.86e	46.71e	0.026d	0.027f	1.809f	1.851e	26.24ab	24.43ab	0.180ab	0.167ab
T_1	0.703b	0.786de	55.41de	62.01de	0.028d	0.028ef	2.239ef	2.202de	28.08ab	29.72ab	0.221ab	0.236ab
T_2	0.887a	1.157abc	71.14bc	94.10abc	0.030cd	0.031def	2.439def	2.528de	34.18a	34.08a	0.272a	0.278ab
T_3	0.923a	1.211a	75.49abc	101.27ab	0.044abcd	0.046bcde	3.604bcde	3.886bcd	35.09a	38.30a	0.288a	0.320a
T_4	0.820ab	0.884bcde	69.23bc	76.94bcd	0.053ab	0.057ab	4.439abc	4.962ab	28.19ab	29.84ab	0.239ab	0.261ab
T_5	0.858ab	0.994abcd	78.52abc	92.29abc	0.060a	0.066a3	5.438a	6.200a	21.04ab	23.38ab	0.192ab	0.215ab
T_6	0.915a	1.178ab	74.59abc	96.45abc	0.037bcd	0.037cdef	2.977cdef	3.038cde	31.63a	31.94ab	0.258ab	0.261ab
T_7	0.901a	1.126abc	79.61ab	102.30ab	0.043abcd	0.049abcd	3.827bcd	4.444bc	28.17ab	30.53ab	0.247ab	0.279ab
T_8	0.880a	0.905bcde	81.19ab	84.23abcd	0.047abc	0.046bcde	4.379abc	4.313bc	25.62ab	27.66ab	0.237ab	0.257ab
T_9	0.924a	1.144abc	86.22a	109.68a	0.054ab	0.056abc	4.957ab	5.304ab	20.33ab	24.10ab	0.188ab	0.229ab
T_{10}	0.798ab	0.867cde	64.56cd	69.87cde	0.027d	0.022f	2.179ef	1.735e	16.65b0	18.03b	0.136b	0.146b
CV (%)	**10.65**	**15.72**	**10.53**	**16.49**	**23.96**	**23.97**	**23.00**	**25.27**	**28.27**	**28.47**	**28.15**	**29.51**
LSD $_{0.05}$	**0.153**	**0.265**	**12.71**	**23.76**	**0.017**	**0.017**	**1.356**	**1.574**	**12.85**	**13.68**	**0.107**	**0.120**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.22b. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by Jute Stick with Barkof GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (µg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute Stick with Bark(Gopalpur Series)												
T_0	0.732c	0.711c	49.04e	47.56c	0.032ab	0.031b	2.180c	2.098c	51.75a	51.21c	0.348c	0.343e
T_1	0.803bc	0.812c	61.58de	93.24b	0.035ab	0.035b	2.703abc	2.659bc	56.70a	57.01abc	0.432abc	0.440cde
T_2	0.913abc	0.984bc	71.69bcd	79.21b	0.027b	0.039ab	2.114c	3.135bc	53.48a	52.47bc	0.421bc	0.421de
T_3	0.834abc	0.958bc	67.41cd	78.22b	0.041ab	0.042ab	3.273abc	3.413abc	62.42a	67.14a	0.503ab	0.551abc
T_4	0.919ab	1.095ab	79.69abc	97.02b	0.039ab	0.043ab	3.330abc	3.862ab	59.64a	63.84ab	0.516ab	0.566ab
T_5	0.928ab	1.051b	82.57ab	95.71b	0.035ab	0.038ab	3.142abc	3.501abc	57.99a	61.72abc	0.516ab	0.563ab
T_6	0.868abc	0.909bc	70.00bcd	71.66b	0.041ab	0.041ab	3.296abc	3.228bc	59.86a	59.05abc	0.482ab	0.465bcd
T_7	0.849abc	0.932bc	71.79bcd	81.54b	0.042ab	0.045ab	3.545ab	3.908ab	63.05a	67.12a	0.538a	0.590a
T_8	1.018a	1.274a	90.14a	124.63a	0.044a	0.054a	3.965a	4.982a	57.87a	63.73ab	0.513ab	0.578ab
T_9	0.876abc	1.013bc	80.53abc	95.04b	0.039ab	0.041ab	3.625ab	3.908ab	52.13a	53.99bc	0.480ab	0.507abcd
T_{10}	0.883abc	1.144ab	70.84bcd	93.81b	0.031ab	0.038ab	2.467bc	3.145bc	53.04a	51.35c	0.427bc	0.421de
CV (%)	**10.93**	**15.80**	**10.30**	**15.99**	**22.52**	**22.52**	**22.69**	**25.55**	**11.28**	**10.84**	**11.70**	**12.63**
LSD $_{0.05}$	**0.162**	**0.277**	**12.61**	**23.57**	**0.014**	**0.016**	**1.175**	**1.488**	**10.90**	**10.83**	**0.093**	**0.106**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.23a. Manganese (Mn) and Copper (Cu) content and uptake by Jute Stick with Barkof Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute Stick with Bark(Sara Series)								
T_0	5.150bc	5.035cd	0.036cd	0.035c	2.911c	1.210d	0.025d	0.022ef
T_1	4.151c	6.472bcd	0.033d	0.051bc	3.108c	3.474bcd	0.050ab	0.059abc
T_2	6.962abc	3.895d	0.056abcd	0.032c	3.990bc	4.162bc	0.025d	0.028def
T_3	7.979ab	8.066abc	0.065abc	0.068ab	4.002bc	4.598bc	0.033bcd	0.039bcde
T_4	8.670ab	9.016ab	0.073ab	0.078ab	6.337ab	7.357a	0.034bcd	0.036cde
T_5	5.360bc	7.020abcd	0.049bcd	0.065b	5.837ab	7.138ab	0.053a	0.066a
T_6	9.235a	9.590ab	0.075ab	0.079ab	3.036c	3.567bcd	0.041abcd	0.049abcd
T_7	7.253abc	7.925abc	0.064abcd	0.072ab	4.623abc	5.381abc	0.027cd	0.033def
T_8	9.144a	10.076a	0.084a	0.094a	5.080abc	5.948ab	0.027cd	0.011f
T_9	6.373abc	6.487bcd	0.060abcd	0.062b	6.679a	7.494a	0.043abc	0.052abcd
T_{10}	3.923c	4.020d	0.032d	0.033c	3.568c	3.148cd	0.054a	0.061ab
CV (%)	**28.18**	**24.28**	**29.61**	**24.70**	**25.08**	**28.31**	**24.49**	**30.55**
LSD $_{0.05}$	**3.219**	**2.901**	**0.029**	**0.025**	**1.898**	**2.331**	**0.016**	**0.021**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.23b. Manganese (Mn) and Copper (Cu) content and uptake by Jute Stick with Barkof GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Jute Stick with Bark(Gopalpur Series)								
T_0	4.127b	4.263b	0.028d	0.028c	2.043d	2.023d	0.014e	0.014d
T_1	6.144ab	5.924ab	0.047abcd	0.046abc	2.676cd	2.924cd	0.021de	0.023cd
T_2	4.210b	6.751ab	0.033bcd	0.054abc	2.664cd	2.966cd	0.021de	0.024cd
T_3	7.093ab	7.589ab	0.057abcd	0.062ab	2.884cd	3.199cd	0.023d	0.026cd
T_4	8.037a	8.347a	0.070a	0.074a	3.600bc	3.916bc	0.031c	0.035bc
T_5	6.854ab	7.183ab	0.061abc	0.065a	4.740a	5.266ab	0.042ab	0.048ab
T_6	4.342b	4.497b	0.075a	0.032bc	2.375d	2.507cd	0.019de	0.020cd
T_7	6.626ab	7.003ab	0.031cd	0.062ab	2.454cd	2.751cd	0.021de	0.024cd
T_8	7.086ab	7.342ab	0.063ab	0.066a	4.591ab	5.232ab	0.040b	0.048ab
T_9	6.326ab	6.721ab	0.057abcd	0.063ab	5.321a	6.058a	0.049a	0.057a
T_{10}	3.551b	5.490ab	0.029d	0.045abc	2.229d	3.157cd	0.018de	0.026cd
CV (%)	**32.28**	**27.78**	**32.63**	**29.50**	**19.49**	**23.99**	**17.30**	**26.84**
LSD $_{0.05}$	**3.300**	**3.024**	**0.028**	**0.027**	**1.067**	**1.477**	**0.008**	**0.014**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.24a. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by rice grain of Sara Series as influenced by different treatments during two years of experiment.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (µg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Rice Grain (Sara Series)												
T_0	0.006f	0.006f	0.116e	0.119e	0.056b	0.055b	1.094d	1.097c	42.70a	42.17a	0.083b	0.083b
T_1	0.013abc	0.013abc	0.507abc	0.522abc	0.059ab	0.059ab	2.303c	2.382b	55.94a	57.00a	0.219a	0.230a
T_2	0.015a	0.016a	0.587a	0.653a	0.059a	0.058ab	2.297c	2.397b	55.79a	55.39a	0.219a	0.227a
T_3	0.011cd	0.012bcd	0.453bc	0.503bc	0.062ab	0.064ab	2.565bc	2.729ab	56.90a	53.01a	0.233a	0.224a
T_4	0.013abc	0.014abc	0.557ab	0.616ab	0.073ab	0.077a	3.182a	3.377a	59.44a	59.27a	0.259a	0.262
T_5	0.010cd	0.011cd	0.436c	0.498bc	0.057ab	0.060ab	2.530bc	2.691ab	62.31a	62.84a	0.276a	0.281
T_6	0.015a	0.015ab	0.605a	0.610ab	0.059ab	0.061ab	2.369c	2.482b	57.03a	56.38a	0.231a	0.230a
T_7	0.007ef	0.008ef	0.289d	0.350d	0.061ab	0.065ab	2.530bc	2.819ab	58.56a	58.82a	0.245a	0.257
T_8	0.014ab	0.014abc	0.605a	0.623ab	0.071ab	0.076a	3.070ab	3.389a	60.92a	65.17a	0.263a	0.290
T_9	0.009de	0.009de	0.405c	0.414cd	0.057ab	0.057b	2.550bc	2.587ab	65.31a	67.28a	0.292a	0.306
T_{10}	0.011bcd	0.012bcd	0.431c	0.494bc	0.064ab	0.061ab	2.497bc	2.495b	58.23a	54.66a	0.227a	0.222a
CV (%)	**14.32**	**14.02**	**14.47**	**16.05**	**13.56**	**15.52**	**13.89**	**16.44**	**22.71**	**27.64**	**24.40**	**28.87**
LSD $_{0.05}$	**0.003**	**0.003**	**0.111**	**0.134**	**0.014**	**0.017**	**0.577**	**0.720**	**22.13**	**28.90**	**0.096**	**0.116**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.
CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant
Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.24b. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by rice grain of GopalpurSeries as influenced by different treatments during two years of experiment.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (μg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Grain (Gopalpur Series)												
T_0	0.006d	0.006c	0.130c	0.130c	0.057a	0.056b	1.251b	1.218b	47.34a	46.57a	0.103b	0.101b
T_1	0.013ab	0.016a	0.527ab	0.674a	0.069a	0.071ab	2.807a	2.943a	63.03a	65.66a	0.255a	0.273a
T_2	0.009bcd	0.009bc	0.386b	0.387b	0.074a	0.073ab	3.158a	3.149a	62.06a	64.10a	0.265a	0.277a
T_3	0.015a	0.016a	0.635a	0.693a	0.059a	0.063ab	2.527a	2.702a	64.80a	69.31a	0.276a	0.298a
T_4	0.015a	0.016a	0.659a	0.704a	0.072a	0.077ab	3.161a	3.397a	66.45a	70.14a	0.291a	0.311a
T_5	0.015a	0.016a	0.662a	0.722a	0.067a	0.072ab	2.943a	3.241a	69.21a	73.04a	0.306a	0.330a
T_6	0.012abc	0.014ab	0.500ab	0.598ab	0.070a	0.069ab	2.929a	2.922a	65.38a	68.52a	0.273a	0.291a
T_7	0.007cd	0.008c	0.308bc	0.357bc	0.060a	0.061ab	2.578a	2.725a	65.26a	67.26a	0.285a	0.301a
T_8	0.011abcd	0.012abc	0.493ab	0.538ab	0.071a	0.078a	3.177a	3.541a	70.16a	70.11a	0.313a	0.315a
T_9	0.008bcd	0.009bc	0.356bc	0.411b	0.068a	0.072ab	3.010a	3.288a	71.63a	75.98a	0.321a	0.347a
T_{10}	0.012abc	0.014ab	0.505ab	0.606ab	0.068a	0.068ab	2.852a	2.940a	67.07a	68.37a	0.281a	0.293a
CV (%)	**26.56**	**26.16**	**27.47**	**26.49**	**16.89**	**15.75**	**17.78**	**16.62**	**25.99**	**28.49**	**27.62**	**29.79**
LSD $_{0.05}$	**0.005**	**0.006**	**0.218**	**0.237**	**0.019**	**0.018**	**0.832**	**0.821**	**28.50**	**32.41**	**0.126**	**0.144**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.25a. Manganese (Mn) and Copper (Cu) content and uptake by rice grain of Sara Series as influenced by different treatments during two years of experiment.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Grain (Sara Series)								
T_0	52.23a	51.59a	0.101b	0.102b	16.44a	15.92a	0.032c	0.032b
T_1	62.95a	65.78a	0.246a	0.265a	18.31a	20.06a	0.072b	0.081a
T_2	60.63a	64.05a	0.239a	0.262a	20.08a	20.87a	0.079ab	0.085a
T_3	67.54a	69.15a	0.278a	0.290a	20.34a	21.71a	0.084ab	0.088a
T_4	72.41a	79.09a	0.315a	0.348a	21.65a	22.06a	0.094ab	0.092a
T_5	80.01a	81.53a	0.352a	0.365a	23.00a	23.07a	0.101ab	0.097a
T_6	73.88a	78.91a	0.297a	0.323a	20.32a	21.55a	0.082ab	0.097a
T_7	73.34a	75.05a	0.307a	0.328a	21.08a	22.14a	0.088ab	0.104a
T_8	75.57a	77.94a	0.327a	0.346a	22.25a	23.62a	0.096ab	0.105a
T_9	78.62a	82.99a	0.351a	0.382a	23.20a	23.85a	0.104a	0.109a
T_{10}	83.25a	84.35a	0.325a	0.343a	20.61a	21.89a	0.080ab	0.089a
CV (%)	**23.83**	**23.85**	**24.80**	**24.81**	**18.80**	**25.05**	**18.62**	**25.97**
$LSD_{0.05}$	**28.63**	**29.75**	**0.120**	**0.128**	**6.578**	**8.767**	**0.026**	**0.039**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;
T_1 :Farmers' practice;
T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});
T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});
T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients;
T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});
T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and
T_{10} : Soil analysis based treatment

Appendix 4.25b. Manganese (Mn) and Copper (Cu) content and uptake by rice grain of GopalpurSeries as influenced by different treatments during two years of experiment.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Grain (Gopalpur Series)								
T_0	54.41a	50.35a	0.118b	0.109b	17.48a	17.48a	0.038b	0.037b
T_1	68.34a	72.78a	0.278a	0.302a	21.97a	22.36a	0.089ab	0.093ab
T_2	71.66a	74.65a	0.306a	0.323a	21.59a	21.78a	0.092ab	0.094ab
T_3	74.92a	78.92a	0.318a	0.339a	22.84a	23.27a	0.097ab	0.100a
T_4	79.28a	82.63a	0.348a	0.365a	23.39a	24.80a	0.103a	0.110a
T_5	77.55a	78.98a	0.343a	0.356a	24.38a	25.21a	0.108a	0.114a
T_6	70.34a	72.29a	0.293a	0.306a	20.24a	21.96a	0.084ab	0.093ab
T_7	66.83a	55.86a	0.289a	0.250ab	23.85a	25.88a	0.103a	0.116a
T_8	74.67a	78.56a	0.333a	0.357a	23.73a	24.22a	0.106a	0.109a
T_9	79.39a	84.63a	0.357a	0.381a	24.93a	25.57a	0.112a	0.117a
T_{10}	71.73a	74.87a	0.301a	0.325a	20.59a	21.54a	0.087ab	0.092ab
CV (%)	**27.06**	**30.86**	**28.34**	**31.84**	**33.75**	**30.39**	**34.76**	**31.04**
LSD $_{0.05}$	**32.87**	**38.22**	**0.143**	**0.167**	**12.73**	**11.89**	**0.055**	**0.051**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.
CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant
Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.26a. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by rice straw of Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (µg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Rice Straw (Sara Series)												
T_0	0.262e	0.258cd	9.00e	9.02d	0.108de	0.107c	3.716e	3.721e	55.49b	56.01bc	0.192e	0.195e
T_1	0.301de	0.331bcd	16.46cd	18.40bc	0.135bcde	0.171a	7.373bcd	9.488ab	60.40ab	59.54bc	0.329cd	0.333cd
T_2	0.299de	0.303bcd	16.34cd	17.29bc	0.173a	0.166a	9.455a	9.474ab	64.07ab	62.06bc	0.351bcd	0.354bcd
T_3	0.254e	0.241d	14.60cde	13.98cd	0.100e	0.090c	5.737d	5.243de	66.92ab	66.62abc	0.383abcd	0.388abcd
T_4	0.420abc	0.403b	24.97ab	24.35b	0.146abc	0.126bc	8.683ab	7.616bcd	69.84ab	70.18ab	0.415abc	0.424abc
T_5	0.511a	0.553a	30.76a	33.72a	0.131bcde	0.111bc	7.929abc	6.781cd	75.81a	73.38ab	0.457a	0.447ab
T_6	0.314cde	0.320bcd	17.51cd	18.26bc	0.159ab	0.148ab	8.936ab	8.443abc	66.36ab	83.15a	0.373abcd	0.472a
T_7	0.324cde	0.322bcd	18.64cd	19.15bc	0.112cde	0.103c	6.514cd	6.149cd	60.81ab	56.97bc	0.353bcd	0.342bcd
T_8	0.233e	0.232d	13.86de	13.99cd	0.137bcd	0.114bc	8.157abc	6.859cd	72.81ab	63.81bc	0.433ab	0.385abcd
T_9	0.486ab	0.533a	29.90a	33.19a	0.125bcde	0.128bc	7.636abcd	10.380a	73.49a	67.67abc	0.449a	0.421abc
T_{10}	0.384bcd	0.379bc	20.94bc	21.36b	0.133bcde	0.116bc	7.217bcd	6.571cd	55.49b	52.02c	0.302d	0.294de
CV (%)	**17.98**	**18.18**	**18.17**	**18.75**	**13.79**	**15.96**	**13.96**	**17.15**	**13.66**	**14.26**	**13.70**	**15.81**
LSD $_{0.05}$	**0.105**	**0.108**	**5.958**	**6.429**	**0.031**	**0.035**	**1.748**	**2.131**	**15.17**	**15.62**	**0.085**	**0.099**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.26b. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by rice straw of GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (µg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Straw (Gopalpur Series)												
T_0	0.286d	0.282d	6.24e	6.11e	0.150b	0.147b	3.269c	3.175d	60.15d	57.92b	0.131e	0.126e
T_1	0.294d	0.341bcd	11.91d	14.15cd	0.172ab	0.178ab	6.968ab	7.369abc	64.90cd	58.44b	0.263d	0.241cd
T_2	0.376abc	0.358bc	16.06bc	15.49bcd	0.166ab	0.174ab	7.124ab	7.534abc	60.97d	55.13b	0.261d	0.239d
T_3	0.343bcd	0.326cd	14.61cd	13.99cd	0.153b	0.144b	6.511b	6.152c	79.29bc	74.91ab	0.337cd	0.322bcd
T_4	0.453a	0.436a	19.90a	19.30a	0.170ab	0.162ab	7.451ab	7.164bc	97.44a	96.76a	0.428ab	0.427ab
T_5	0.414ab	0.367abc	18.22ab	16.47abc	0.214a	0.215a	9.444a	9.645a	82.94ab	80.51ab	0.365abc	0.363ab
T_6	0.383abc	0.366bc	16.02bc	15.46bcd	0.179ab	0.166ab	7.531ab	7.002bc	91.09ab	89.04a	0.381abc	0.376ab
T_7	0.298d	0.275d	12.92cd	12.30d	0.165ab	0.165ab	7.132ab	7.409abc	79.43bc	78.19ab	0.345bc	0.349abc
T_8	0.428a	0.382abc	19.09ab	17.31abc	0.185ab	0.174ab	8.199ab	7.889abc	99.78a	96.14a	0.445a	0.436a
T_9	0.415ab	0.407ab	17.93ab	17.93ab	0.197ab	0.184ab	8.486ab	8.141abc	90.47ab	88.32a	0.394abc	0.388ab
T_{10}	0.326cd	0.340bcd	13.63cd	14.79bcd	0.180ab	0.204a	7.543ab	8.868ab	84.27ab	80.49ab	0.353bc	0.349abc
CV (%)	**11.29**	**11.04**	**11.70**	**12.30**	**16.82**	**15.64**	**17.60**	**17.28**	**11.61**	**17.48**	**13.02**	**17.95**
LSD $_{0.05}$	**0.070**	**0.066**	**3.000**	**3.092**	**0.050**	**0.046**	**2.158**	**2.137**	**15.92**	**23.03**	**0.074**	**0.100**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.27a. Manganese (Mn)) and Copper (Cu) content and uptake by rice straw of Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Straw (Sara Series)								
T_0	96.74c	93.87c	0.333d	0.327d	2.018bc	2.199bc	0.007c	0.008d
T_1	110.83c	109.44c	0.606c	0.612c	2.788ab	2.799abc	0.015ab	0.016abc
T_2	120.49bc	119.18abc	0.659c	0.679bc	2.842ab	3.013ab	0.016ab	0.017abc
T_3	125.82abc	118.97abc	0.723bc	0.691bc	2.773ab	2.896abc	0.016ab	0.017abc
T_4	132.21abc	127.34abc	0.787abc	0.769abc	3.065a	3.186ab	0.018a	0.019ab
T_5	155.81ab	146.41ab	0.938ab	0.892ab	2.900ab	2.985ab	0.017a	0.018ab
T_6	127.30abc	126.89abc	0.710bc	0.724bc	2.702ab	2.705abc	0.015ab	0.016abc
T_7	122.87abc	118.26abc	0.708bc	0.703bc	2.049bc	2.280bc	0.012bc	0.014bcd
T_8	131.92abc	127.28abc	0.785abc	0.768abc	3.452a	3.684a	0.020a	0.022a
T_9	165.67a	158.93a	1.019a	0.991a	2.521abc	2.585abc	0.015ab	0.016abc
T_{10}	138.77abc	132.56abc	0.756bc	0.747abc	1.717c	1.696c	0.009c	0.009cd
CV (%)	**17.61**	**18.03**	**17.91**	**18.83**	**18.66**	**24.31**	**18.92**	**26.70**
LSD $_{0.05}$	**38.72**	**38.27**	**0.221**	**0.229**	**0.828**	**1.124**	**0.005**	**0.007**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.27b. Manganese (Mn) and Copper (Cu) content and uptake by rice straw of GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Rice Straw (Gopalpur Series)								
T_0	72.37c	69.61c	0.157d	0.151d	2.839a	2.974a	0.006b	0.007b
T_1	81.75c	80.28c	0.332c	0.333c	4.042a	4.102a	0.016a	0.017a
T_2	89.69bc	87.44c	0.383bc	0.378c	4.321a	4.414a	0.019a	0.019a
T_3	93.10bc	93.01bc	0.395bc	0.399bc	2.932a	3.074a	0.012a	0.013a
T_4	118.73ab	116.19ab	0.521ab	0.514ab	3.271a	3.474a	0.014a	0.016a
T_5	139.43a	136.30a	0.615a	0.613a	3.520a	3.763a	0.016a	0.017a
T_6	91.04bc	88.74c	0.380bc	0.374c	4.004a	4.170a	0.017a	0.018a
T_7	88.52bc	84.94c	0.383bc	0.380c	3.409a	3.602a	0.015a	0.016a
T_8	128.01a	118.39ab	0.571a	0.537a	3.757a	3.867a	0.017a	0.018a
T_9	134.81a	132.48a	0.583a	0.584a	4.102a	4.228a	0.017a	0.018a
T_{10}	88.41bc	79.98c	0.370c	0.347c	3.736a	3.981a	0.015a	0.017a
CV (%)	**17.71**	**15.40**	**18.25**	**17.09**	**22.20**	**22.64**	**22.65**	**22.02**
LSD $_{0.05}$	**30.69**	**25.79**	**0.132**	**0.121**	**1.365**	**1.452**	**0.006**	**0.006**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.28. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by mustard grain of Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (µg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Mustard Grain (Sara Series)												
T_0	0.275b	0.264d	1.455e	1.413g	0.241b	0.204c	1.274e	1.092e	325.42c	363.17c	0.172e	0.194f
T_1	0.314ab	0.322cd	2.511d	2.548fg	0.346a	0.354ab	2.756d	2.788d	440.93b	442.67ab	0.351d	0.350e
T_2	0.330ab	0.354bcd	2.608d	2.752efg	0.340a	0.339b	2.674d	2.634d	462.13ab	414.80bc	0.365d	0.322e
T_3	0.325ab	0.411abc	3.091cd	3.785def	0.339a	0.351ab	3.208d	3.213d	440.93b	453.77ab	0.418d	0.417de
T_4	0.339ab	0.433ab	3.914bc	4.906bcd	0.356a	0.372a	4.094bc	4.200bc	474.63ab	490.60a	0.542c	0.554bc
T_5	0.353a	0.457ab	4.320ab	5.511abc	0.359a	0.360ab	4.379bc	4.318bc	499.13ab	509.10a	0.605bc	0.612abc
T_6	0.324ab	0.395abc	3.793bc	4.538bcd	0.340a	0.348ab	3.982c	3.968c	450.30b	441.30ab	0.530c	0.506cd
T_7	0.323ab	0.448ab	4.134abc	5.604abc	0.346a	0.340b	4.415bc	4.260bc	477.30ab	484.10ab	0.611bc	0.608abc
T_8	0.334ab	0.449ab	4.621ab	6.090ab	0.348a	0.356ab	4.803ab	4.821ab	494.17ab	505.37a	0.683ab	0.685ab
T_9	0.349a	0.470a	5.076a	6.705a	0.355a	0.364ab	5.141a	5.206a	521.17a	505.73a	0.755a	0.724a
T_{10}	0.312ab	0.320cd	4.198abc	4.295cde	0.351a	0.363ab	4.738ab	4.814ab	467.37ab	449.20ab	0.634bc	0.595abc
CV (%)	**10.65**	**14.10**	**16.44**	**20.11**	**5.18**	**4.29**	**10.49**	**10.25**	**7.74**	**8.18**	**12.63**	**14.07**
LSD $_{0.05}$	**0.059**	**0.094**	**1.005**	**1.491**	**0.030**	**0.025**	**0.670**	**0.652**	**60.19**	**63.69**	**0.110**	**0.121**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.29. Manganese (Mn) and Copper (Cu) content and uptake by mustard grain of Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Mustard Grain (Sara Series)								
T_0	12.22d	14.02e	0.006g	0.008f	4.235e	4.686c	0.002f	0.002e
T_1	16.34c	21.08cd	0.013f	0.017e	5.206de	5.521bc	0.004ef	0.004de
T_2	17.83bc	24.36abcd	0.014ef	0.019de	5.886bcd	6.076bc	0.005e	0.005de
T_3	16.73c	23.95abcd	0.016def	0.021cde	6.199abcd	6.238bc	0.006de	0.006cd
T_4	17.74bc	27.13abc	0.020bcd	0.031bc	6.663abcd	6.658ab	0.008bcd	0.008bc
T_5	20.96ab	28.13ab	0.025b	0.034b	7.186ab	7.176ab	0.009abc	0.009b
T_6	16.11c	24.65abcd	0.019cde	0.029bc	5.322cde	6.583ab	0.006cde	0.008bc
T_7	17.69bc	22.56bcd	0.023bc	0.028bcd	6.808abcd	6.848ab	0.009abc	0.009b
T_8	18.15bc	26.65abcd	0.025b	0.036ab	7.048abc	7.274ab	0.010ab	0.010ab
T_9	22.41a	30.17a	0.033a	0.043a	7.714a	8.245a	0.011a	0.012a
T_{10}	17.13c	20.43d	0.023bc	0.027bcd	5.931bcd	6.011bc	0.008bcd	0.008bc
CV (%)	**10.07**	**13.70**	**15.18**	**19.36**	**14.52**	**14.26**	**19.02**	**19.09**
$LSD_{0.05}$	**2.997**	**5.549**	**0.005**	**0.009**	**1.525**	**1.566**	**0.002**	**0.002**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.30. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by mustard stoverof Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (µg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Mustard Stover (Sara Series)												
T_0	0.741e	0.722e	19.39f	18.08f	0.133b	0.116d	3.482d	2.920d	356.92c	371.27c	0.937f	0.928f
T_1	0.911de	0.907de	29.31ef	28.48ef	0.217ab	0.247bc	6.920cd	7.761c	555.27ab	565.60b	1.781de	1.778e
T_2	1.144bcd	1.025cde	37.98cde	34.07de	0.244a	0.227c	8.173bc	7.477c	527.57b	619.83ab	1.754e	2.050cde
T_3	1.282abc	1.314abc	43.85bcd	44.10cd	0.254a	0.276abc	8.698bc	9.235c	591.07ab	601.43ab	2.023cde	2.025cde
T_4	1.370ab	1.396ab	48.53bc	48.64c	0.304a	0.313abc	10.756abc	10.845bc	599.20ab	618.47ab	2.124bcd	2.152cd
T_5	1.476ab	1.497a	52.91ab	82.36a	0.319a	0.356ab	11.509ab	19.550a	624.97ab	636.87ab	2.243abc	3.502a
T_6	0.940de	1.130bcd	33.37de	39.57cde	0.267a	0.237bc	9.441abc	8.256c	550.57ab	562.47b	1.967cde	1.961de
T_7	1.341ab	1.374abc	48.53bc	47.98c	0.286a	0.321abc	10.311abc	11.325bc	617.20ab	625.73ab	2.231abc	2.198cd
T_8	1.442ab	1.426ab	53.95ab	50.95c	0.306a	0.322abc	11.483ab	11.506bc	639.00a	653.60ab	2.392ab	2.334bc
T_9	1.548a	1.647a	61.28a	64.29b	0.329a	0.375a	12.933a	14.647b	650.33a	670.17a	2.563a	2.610b
T_{10}	0.963cde	0.900de	35.52de	32.48de	0.270a	0.262abc	9.916abc	9.484c	574.97ab	583.03ab	2.115bcd	2.102cde
CV (%)	**15.09**	**15.84**	**15.52**	**16.53**	**22.88**	**22.64**	**22.94**	**23.59**	**9.02**	**9.06**	**9.22**	**8.75**
LSD $_{0.05}$	**0.306**	**0.325**	**11.10**	**12.49**	**0.103**	**0.106**	**3.660**	**4.104**	**87.33**	**90.73**	**0.314**	**0.318**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.31. Manganese (Mn) and Copper (Cu) content and uptake by mustard stoverof Sara Series as influenced by different treatments during two years of field experiments.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2	Y-1	Y-2
Mustard Stover (Sara Series)								
T_0	3.083d	3.240d	0.008e	0.008e	9.74a	9.73b	0.026d	0.024d
T_1	5.178c	5.198bc	0.017d	0.016d	11.18a	11.91ab	0.036cd	0.038cd
T_2	5.759abc	5.359abc	0.019cd	0.018cd	12.36a	11.89ab	0.041bc	0.039cd
T_3	5.368bc	5.898abc	0.018cd	0.020cd	11.68a	11.53ab	0.040bc	0.039cd
T_4	6.118abc	6.231abc	0.022bc	0.022bc	12.46a	12.58ab	0.044abc	0.044c
T_5	6.440ab	6.370ab	0.023ab	0.035a	13.46a	13.68ab	0.048ab	0.075a
T_6	5.308bc	5.066c	0.019cd	0.018cd	12.68a	13.56ab	0.045abc	0.047bc
T_7	5.638abc	5.867abc	0.020bcd	0.020cd	11.98a	13.82ab	0.043abc	0.049bc
T_8	5.840abc	6.017abc	0.022bc	0.021bc	12.53a	14.24ab	0.047abc	0.051bc
T_9	6.720a	6.507a	0.027a	0.025b	13.75a	15.68ab	0.054a	0.061ab
T_{10}	5.814abc	5.784abc	0.021bc	0.021bcd	11.61a	11.99ab	0.043abc	0.043c
CV (%)	**10.92**	**11.84**	**10.05**	**12.05**	**16.99**	**17.90**	**15.25**	**19.30**
$LSD_{0.05}$	**1.030**	**1.122**	**0.003**	**0.004**	**3.491**	**3.875**	**0.011**	**0.015**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.
CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant
Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.32. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by lentil grain of GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (µg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Lentil Grain (Gopalpur Series)												
T_0	0.071c	0.066d	0.672e	0.598f	0.102b	0.107c	0.964e	0.967d	42.43d	45.04d	0.040g	0.041d
T_1	0.098bc	0.103bc	1.254cd	1.349e	0.141a	0.148abc	1.789d	1.935bc	54.03c	58.73c	0.069f	0.077c
T_2	0.123ab	0.129ab	1.662bc	1.822bc	0.143a	0.152ab	1.927bcd	2.143abc	59.66bc	63.00bc	0.080ef	0.089c
T_3	0.084c	0.087cd	1.323cd	1.413de	0.149a	0.142abc	2.353abcd	2.305ab	61.47abc	65.16bc	0.097bcd	0.105b
T_4	0.103bc	0.109bc	1.649bc	1.803bcd	0.167a	0.155ab	2.665a	2.574a	64.07ab	67.51bc	0.102ab	0.112ab
T_5	0.094bc	0.099c	1.435cd	1.542cde	0.157a	0.150abc	2.401abc	2.343ab	67.78ab	70.03ab	0.103ab	0.109ab
T_6	0.081c	0.087cd	1.067de	1.182e	0.138a	0.118bc	1.825cd	1.601c	64.50ab	65.30bc	0.085cde	0.088c
T_7	0.101bc	0.108bc	1.657bc	1.844bc	0.148a	0.146abc	2.442ab	2.481ab	60.65bc	63.48bc	0.099abc	0.107b
T_8	0.145a	0.151a	2.454a	2.625a	0.158a	0.148abc	2.677a	2.571a	66.78ab	69.93ab	0.113a	0.122a
T_9	0.133a	0.137a	1.962b	2.093b	0.175a	0.171a	2.576a	2.626a	70.51a	75.10a	0.104ab	0.114ab
T_{10}	0.102bc	0.107bc	1.318cd	1.426de	0.154a	0.128abc	1.964bcd	1.707c	64.49ab	65.71bc	0.083def	0.088c
CV (%)	**15.95**	**14.15**	**17.23**	**13.38**	**13.59**	**15.73**	**14.37**	**15.34**	**7.89**	**7.97**	**9.23**	**7.88**
LSD $_{0.05}$	**0.028**	**0.026**	**0.426**	**0.364**	**0.034**	**0.038**	**0.522**	**0.549**	**8.218**	**8.697**	**0.014**	**0.013**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.33. Manganese (Mn) and Copper (Cu) content and uptake by lentil grain of GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Lentil Grain (Gopalpur Series)								
T_0	10.87d	11.20e	0.010e	0.010f	8.73f	8.73f	0.008d	0.008g
T_1	15.13c	15.82cd	0.019d	0.021e	11.71ef	12.60e	0.015c	0.016f
T_2	16.67bc	16.70cd	0.022cd	0.024cde	14.81bcde	15.14cde	0.020bc	0.022def
T_3	13.58cd	14.14d	0.022cd	0.023de	15.78abcd	16.14cde	0.025ab	0.026abcd
T_4	15.24c	16.17cd	0.024bcd	0.027bcd	17.01abc	18.20abcd	0.027a	0.030abc
T_5	19.63ab	20.41ab	0.030ab	0.032ab	18.55ab	20.66a	0.028a	0.032a
T_6	17.96bc	18.01bc	0.024bcd	0.025cde	19.22a	18.66abc	0.025ab	0.025bcd
T_7	15.83bc	16.83cd	0.026abc	0.029abcd	13.59cde	14.07de	0.023ab	0.024cde
T_8	16.43bc	16.78cd	0.028abc	0.029abc	14.97bcde	15.20cde	0.026ab	0.027abcd
T_9	21.71a	22.05a	0.032a	0.034a	16.25abcd	20.10ab	0.024ab	0.031ab
T_{10}	16.41bc	17.12cd	0.021cd	0.023de	12.89de	13.95de	0.016c	0.019ef
CV (%)	**13.92**	**10.26**	**15.32**	**12.65**	**14.28**	**14.35**	**15.27**	**13.74**
LSD $_{0.05}$	**3.845**	**2.925**	**0.006**	**0.005**	**3.595**	**3.833**	**0.006**	**0.005**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B;
T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});
T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});
T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.34. Calcium (Ca), Magnesium (Mg) and Iron (Fe) content and uptake by lentil stoverof GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	Ca content (%)		Ca uptake (kg ha^{-1})		Mg content (%)		Mg uptake (kg ha^{-1})		Fe content (µg g^{-1})		Fe uptake (kg ha^{-1})	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
Lentil Stover (Gopalpur Series)												
T_0	0.525e	0.541c	6.47f	6.44c	0.195d	0.183c	2.399c	2.174d	92.31a	97.53d	0.114f	0.117e
T_1	0.648d	0.720b	9.19e	12.77b	0.306c	0.272b	4.332b	3.989c	118.81b	124.65c	0.169e	0.183d
T_2	0.892a	0.741ab	13.08ab	12.67b	0.313bc	0.323a	5.570a	4.824abc	119.77c	121.19c	0.176de	0.180d
T_3	0.657cd	0.787ab	9.99de	11.31b	0.317bc	0.310ab	4.755ab	4.876abc	132.43abc	133.81abc	0.201bcd	0.211bcd
T_4	0.805ab	0.799ab	13.07ab	13.90ab	0.318bc	0.326a	5.445a	5.457a	136.33abc	140.58abc	0.221abc	0.235ab
T_5	0.769abc	0.816ab	12.15bc	12.60b	0.332abc	0.271b	5.025ab	4.358bc	143.46a	147.37ab	0.228ab	0.236ab
T_6	0.718bcd	0.819ab	10.87cde	11.61b	0.336abc	0.327a	5.631a	5.112ab	127.96abc	128.33bc	0.194cde	0.201cd
T_7	0.777abc	0.834ab	12.73abc	13.42ab	0.351abc	0.272b	5.207ab	4.542abc	131.07abc	134.68abc	0.214abc	0.225abc
T_8	0.851a	0.854ab	14.56a	15.81a	0.370ab	0.305ab	5.699a	5.278ab	140.12ab	141.30abc	0.240a	0.245a
T_9	0.803ab	0.873ab	12.76abc	13.17ab	0.379a	0.312ab	5.593a	5.039ab	146.34a	150.36a	0.233ab	0.242ab
T_{10}	0.792ab	0.910a	11.21bcd	11.95b	0.380a	0.303ab	5.386a	4.429bc	121.74bc	123.54c	0.172de	0.180d
CV (%)	**8.79**	**11.55**	**9.25**	**11.97**	**9.19**	**9.02**	**11.17**	**10.49**	**7.79**	**8.12**	**8.61**	**8.37**
LSD $_{0.05}$	**0.111**	**0.155**	**1.795**	**2.501**	**0.051**	**0.045**	**0.947**	**0.808**	**16.91**	**18.04**	**0.029**	**0.029**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix 4.35. Manganese (Mn) and Copper (Cu) content and uptake by lentil stoverof GopalpurSeries as influenced by different treatments during two years of field experiments.

Treatment No.	Mn content ($\mu g\ g^{-1}$)		Mn uptake ($kg\ ha^{-1}$)		Cu content ($\mu g\ g^{-1}$)		Cu uptake ($kg\ ha^{-1}$)	
	Y-1	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**	**Y-1**	**Y-2**
T_0	11.22d	12.14f	0.014e	0.015f	9.94c	10.22c	0.012e	0.012d
T_1	14.89cd	15.11ef	0.021de	0.022e	14.65bc	15.40bc	0.021de	0.022cd
T_2	18.51abc	18.96abcde	0.027bcd	0.028cde	15.01bc	16.30bc	0.022cde	0.025cd
T_3	14.28cd	16.11def	0.022cde	0.025de	19.34ab	21.25ab	0.029bcd	0.033abc
T_4	17.46bc	18.09bcde	0.028abcd	0.030bcde	21.38ab	22.41ab	0.035abcd	0.037abc
T_5	21.70ab	22.91ab	0.034ab	0.037ab	24.32a	26.28a	0.039ab	0.042ab
T_6	21.07ab	22.21abc	0.032abc	0.035abc	28.16a	22.28ab	0.043ab	0.035abc
T_7	18.17abc	18.44abcde	0.030abcd	0.031bcd	21.72ab	22.35ab	0.036abc	0.037abc
T_8	19.45abc	21.32abcd	0.033ab	0.037ab	26.20a	27.23a	0.045a	0.047a
T_9	23.78a	24.30a	0.038a	0.039a	28.54a	29.58a	0.046a	0.048a
T_{10}	16.06bcd	16.43cdef	0.023cde	0.024de	20.20ab	20.35ab	0.029bcd	0.030bc
CV (%)	**17.61**	**16.88**	**20.09**	**14.79**	**22.89**	**23.36**	**23.30**	**23.89**
LSD $_{0.05}$	**5.329**	**5.353**	**0.009**	**0.007**	**8.087**	**8.404**	**0.013**	**0.014**

Treatment means having common letter(s) are not significantly different from each other at 5% level of significance by DMRT.

CV = Coefficient of Variation; **LSD** = Least Significance Difference; **NS** = Non Significant

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control; T_1 :Farmers' practice; T_2 : Farmers' practice + recom. S&B; T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1}); T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1}); T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1}); T_6 :Recom. fertilizer nutrients; T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1}); T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1}); T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and T_{10} : Soil analysis based treatment

Appendix4.36. Nutrient uptake by different crops under Jute-T. aman-Mustard cropping pattern of Sara Series and Jute-T. aman-Lentil cropping pattern of Gopalpur Series as influenced by treatment T_0, T_1, T_2, T_3, T_4, T_5, T_6,T_7,T_8, T_9 and T_{10}during two years of field experiments.

Nutrients	Nutrient Uptake (kg ha^{-1})															
	Sara Series								Gopalpur Series							
	Y-1				Y-2				Y-1				Y-2			
	Jute	T. aman	Mustard	Total	Jute	T. aman	Mustard	Total	Jute	T. aman	Lentil	Total	Jute	T. aman	Lentil	Total
Treatment T_0																
Nitrogen	36.56	36.72	20.05	93.33	35.23	36.43	18.98	90.64	33.12	33.80	40.23	107.15	32.67	32.89	35.57	101.13
Phosphorus	7.11	5.36	3.67	16.14	6.68	5.34	3.33	15.35	6.89	5.23	2.11	14.23	6.32	5.07	1.88	13.27
Potassium	63.64	47.40	26.06	137.10	56.45	46.26	23.52	126.23	62.07	41.59	8.72	112.38	60.00	40.29	7.89	108.18
Sulphur	7.13	3.118	3.76	14.01	6.89	3.094	3.51	13.50	7.24	2.484	1.45	11.18	6.86	2.396	1.44	10.70
Calcium	47.85	9.12	20.85	77.82	46.71	9.13	19.49	75.33	49.04	6.36	7.14	62.55	47.56	6.24	7.04	60.84
Magnesium	1.808	4.81	4.76	11.37	1.851	4.82	4.01	10.68	2.179	4.52	3.363	10.06	2.098	4.39	3.141	9.63
Iron	0.180	0.275	1.109	1.564	0.167	0.279	1.122	1.567	0.348	0.234	0.153	0.735	0.343	0.227	0.158	0.727
Manganese	0.036	0.434	0.015	0.484	0.034	0.430	0.016	0.480	0.028	0.275	0.024	0.327	0.029	0.260	0.024	0.313
Zinc	0.101	0.133	0.046	0.280	0.094	0.138	0.044	0.277	0.079	0.118	0.045	0.241	0.078	0.115	0.046	0.239
Copper	0.025	0.039	0.028	0.092	0.022	0.039	0.027	0.088	0.014	0.044	0.020	0.078	0.013	0.044	0.020	0.077
Boron	0.110	0.005	0.021	0.136	0.104	0.005	0.021	0.130	0.103	0.004	0.006	0.113	0.100	0.004	0.006	0.110
Treatment T_1																
Nitrogen	74.38	76.82	31.26	182.47	74.87	82.29	35.70	192.86	58.79	75.84	74.96	209.58	58.15	86.59	64.98	209.72
Phosphorus	8.59	12.12	8.29	29.00	9.41	12.64	8.16	30.21	11.10	12.99	5.72	29.82	9.30	12.06	6.24	27.61
Potassium	106.25	138.21	43.32	287.78	96.14	169.81	51.77	317.72	113.18	126.85	14.98	255.02	82.38	153.58	15.66	251.62
Sulphur	13.37	6.339	7.83	27.54	12.42	6.993	7.40	26.81	12.25	6.034	2.07	20.36	10.94	6.301	2.24	19.49
Calcium	55.41	16.97	31.82	104.20	62.01	18.93	31.03	111.96	61.58	12.44	10.45	84.47	93.24	14.83	14.12	122.19
Magnesium	2.239	9.68	9.68	21.59	2.202	11.87	10.55	24.62	2.703	9.77	6.121	18.60	2.660	10.31	5.924	18.90
Iron	0.221	0.547	2.132	2.901	0.236	0.563	2.128	2.927	0.433	0.517	0.238	1.188	0.440	0.514	0.261	1.215
Manganese	0.033	0.852	0.030	0.915	0.051	0.877	0.033	0.961	0.047	0.610	0.040	0.697	0.046	0.635	0.043	0.724
Zinc	0.145	0.297	0.082	0.524	0.185	0.337	0.081	0.602	0.130	0.297	0.093	0.521	0.117	0.322	0.099	0.538
Copper	0.050	0.087	0.040	0.177	0.059	0.097	0.042	0.197	0.021	0.106	0.036	0.162	0.022	0.110	0.039	0.171
Boron	0.136	0.010	0.035	0.181	0.142	0.011	0.042	0.194	0.140	0.012	0.015	0.166	0.143	0.012	0.015	0.170

Continue:

Nutrients	Nutrient Uptake (kg ha^{-1})															
	Sara Series								Gopalpur Series							
	Y-1				Y-2				Y-1				Y-2			
	Jute	T. aman	Mustard	Total	Jute	T. aman	Mustard	Total	Jute	T. aman	Lentil	Total	Jute	T. aman	Lentil	Total
Treatment T_2																
Nitrogen	48.21	78.54	37.72	164.47	46.91	82.56	38.22	167.69	48.86	79.85	74.87	203.58	49.53	91.40	74.36	215.29
Phosphorus	10.85	12.70	8.62	32.17	11.98	12.04	8.19	32.21	10.52	13.28	5.75	29.55	11.84	13.71	6.64	32.19
Potassium	111.38	143.53	56.01	310.92	138.15	172.22	49.26	359.63	82.97	116.26	15.78	215.01	96.97	130.32	17.02	244.31
Sulphur	13.41	6.41	10.28	30.10	14.11	8.76	10.49	33.36	9.18	6.07	3.15	18.40	9.84	9.00	3.37	22.21
Calcium	71.14	16.93	40.59	128.66	94.10	17.94	36.83	148.86	71.69	16.45	14.74	102.88	79.21	15.88	14.50	109.59
Magnesium	2.439	11.75	10.85	25.04	2.528	11.87	10.11	24.51	2.114	10.28	7.496	19.89	3.135	10.68	6.967	20.78
Iron	0.272	0.569	2.119	2.960	0.278	0.580	2.372	3.231	0.421	0.526	0.256	1.202	0.421	0.516	0.269	1.206
Manganese	0.056	0.898	0.033	0.987	0.032	0.942	0.037	1.010	0.033	0.689	0.050	0.772	0.054	0.701	0.052	0.807
Zinc	0.167	0.315	0.087	0.569	0.185	0.348	0.088	0.621	0.151	0.319	0.094	0.564	0.198	0.330	0.099	0.627
Copper	0.025	0.094	0.046	0.165	0.028	0.103	0.044	0.175	0.021	0.111	0.042	0.173	0.024	0.113	0.046	0.183
Boron	0.172	0.012	0.039	0.223	0.218	0.013	0.045	0.276	0.185	0.010	0.017	0.212	0.200	0.011	0.017	0.228
Treatment T_3																
Nitrogen	55.19	84.18	38.75	178.12	55.27	90.20	43.70	189.17	52.89	78.10	83.01	214.00	54.03	90.10	82.52	226.65
Phosphorus	14.06	15.19	10.20	39.45	15.66	14.72	9.48	39.86	13.48	13.46	6.12	33.06	14.74	13.47	7.49	35.70
Potassium	118.34	156.29	58.26	332.89	131.98	184.70	57.93	374.61	141.89	118.00	16.65	276.54	92.90	148.03	18.04	258.97
Sulphur	13.83	6.65	10.93	31.41	16.53	7.36	10.26	34.15	10.04	5.65	2.76	18.45	9.32	7.08	2.93	19.33
Calcium	75.49	15.05	46.95	137.49	101.27	14.48	47.88	163.64	67.41	15.24	11.32	93.96	78.22	14.68	12.72	105.62
Magnesium	3.604	8.30	11.91	23.81	3.886	7.97	12.45	24.31	3.273	9.04	7.108	19.42	3.413	8.85	7.181	19.45
Iron	0.288	0.616	2.441	3.345	0.320	0.613	2.442	3.375	0.502	0.613	0.299	1.414	0.550	0.620	0.316	1.486
Manganese	0.065	1.002	0.034	1.102	0.068	0.981	0.041	1.090	0.057	0.713	0.043	0.813	0.062	0.738	0.048	0.848
Zinc	0.139	0.349	0.091	0.579	0.193	0.380	0.093	0.666	0.146	0.283	0.097	0.526	0.155	0.305	0.105	0.565
Copper	0.033	0.100	0.046	0.178	0.039	0.108	0.045	0.192	0.023	0.109	0.054	0.187	0.026	0.113	0.060	0.199
Boron	0.228	0.011	0.044	0.283	0.268	0.011	0.052	0.331	0.256	0.012	0.013	0.281	0.281	0.011	0.013	0.305

Continue:

Nutrients	Nutrient Uptake (kg ha^{-1})															
	Sara Series								Gopalpur Series							
	Y-1				Y-2				Y-1				Y-2			
	Jute	T. aman	Mustard	Total	Jute	T. aman	Mustard	Total	Jute	T. aman	Lentil	Total	Jute	Jute	T. aman	Total
Treatment T_4																
Nitrogen	50.65	93.63	56.39	200.67	51.14	102.16	56.70	210.00	45.00	74.61	87.34	206.95	45.97	91.90	90.31	228.18
Phosphorus	11.35	15.00	12.29	38.64	12.60	13.96	12.29	38.85	25.56	16.11	6.62	48.29	20.84	16.01	8.01	44.86
Potassium	131.08	167.26	63.76	362.10	113.55	202.10	64.97	380.62	149.22	119.28	16.91	285.41	105.44	164.10	17.87	287.41
Sulphur	10.06	8.67	11.60	30.33	15.42	9.19	11.21	35.82	13.00	5.56	3.12	21.68	13.25	7.09	3.31	23.65
Calcium	69.23	25.53	52.44	147.20	76.94	24.97	53.55	155.46	79.70	20.56	14.72	114.97	97.02	20.00	15.70	132.73
Magnesium	4.439	11.87	14.85	31.15	4.962	10.99	15.04	31.00	3.330	10.61	8.110	22.05	3.862	10.56	8.031	22.45
Iron	0.239	0.674	2.666	3.579	0.261	0.686	2.706	3.654	0.516	0.719	0.323	1.559	0.566	0.738	0.347	1.651
Manganese	0.073	1.101	0.042	1.216	0.078	1.117	0.053	1.247	0.070	0.870	0.053	0.992	0.074	0.878	0.057	1.010
Zinc	0.152	0.412	0.105	0.669	0.193	0.462	0.109	0.764	0.202	0.325	0.108	0.635	0.214	0.343	0.117	0.674
Copper	0.034	0.112	0.052	0.198	0.036	0.117	0.052	0.205	0.031	0.117	0.062	0.210	0.035	0.125	0.068	0.227
Boron	0.247	0.015	0.050	0.312	0.321	0.015	0.056	0.392	0.303	0.016	0.014	0.333	0.319	0.015	0.014	0.348
Treatment T_5																
Nitrogen	88.97	97.86	61.44	248.27	87.71	108.82	74.13	270.66	69.97	81.51	83.94	235.42	69.75	105.18	87.78	262.71
Phosphorus	17.39	15.77	13.29	46.45	17.96	15.74	14.52	48.22	12.32	14.77	6.49	33.58	13.28	15.09	7.57	35.94
Potassium	150.06	167.57	69.02	386.65	110.62	196.01	103.88	410.51	137.94	123.39	15.87	277.20	101.18	153.95	16.46	271.59
Sulphur	16.02	9.87	12.19	38.08	16.88	10.65	18.54	46.07	12.01	7.13	3.34	22.48	12.12	7.38	3.52	23.02
Calcium	78.52	31.20	57.23	166.95	92.29	34.22	87.88	214.38	82.57	18.89	13.59	115.04	95.70	17.19	14.14	127.04
Magnesium	5.439	10.46	15.89	31.79	6.200	9.47	23.87	39.54	3.142	12.39	7.425	22.95	3.501	12.89	6.701	23.09
Iron	0.192	0.733	2.849	3.774	0.215	0.729	4.114	5.058	0.516	0.671	0.331	1.518	0.562	0.692	0.346	1.600
Manganese	0.049	1.291	0.048	1.388	0.065	1.257	0.069	1.391	0.061	0.958	0.064	1.083	0.065	0.970	0.069	1.104
Zinc	0.178	0.483	0.117	0.778	0.200	0.513	0.163	0.876	0.120	0.343	0.119	0.582	0.142	0.373	0.126	0.641
Copper	0.053	0.119	0.057	0.229	0.066	0.122	0.084	0.272	0.042	0.123	0.067	0.232	0.048	0.131	0.075	0.253
Boron	0.202	0.015	0.052	0.269	0.243	0.013	0.086	0.342	0.170	0.012	0.016	0.198	0.188	0.012	0.016	0.216

Continue:

Nutrients	Nutrient Uptake (kg ha^{-1})															
	Sara Series								Gopalpur Series							
	Y-1				Y-2				Y-1				Y-2			
	Jute	T. aman	Mustard	Total	Jute	T. aman	Mustard	Total	Jute	T. aman	Lentil	Total	Jute	Jute	T. aman	Total
Treatment T_6																
Nitrogen	74.78	91.75	52.76	219.29	74.37	90.73	46.03	211.13	60.94	74.46	72.90	208.30	57.49	85.50	67.01	210.00
Phosphorus	13.17	11.30	12.08	36.55	13.41	11.89	12.63	37.93	11.34	13.21	5.36	29.91	11.52	13.27	5.45	30.24
Potassium	141.52	159.42	60.78	361.72	78.54	156.57	60.43	295.54	104.33	124.05	15.14	243.52	113.01	121.51	15.52	250.04
Sulphur	15.87	8.57	9.38	33.82	15.21	9.21	8.82	33.24	10.88	5.75	2.92	19.55	10.06	7.54	3.09	20.69
Calcium	74.59	18.11	37.16	129.86	96.45	18.87	44.11	159.42	70.00	16.52	11.94	98.45	71.66	16.05	12.79	100.50
Magnesium	2.977	11.30	13.42	27.70	3.038	10.93	12.22	26.19	3.296	10.46	7.457	21.21	3.228	9.92	6.713	19.87
Iron	0.258	0.605	2.497	3.360	0.261	0.701	2.468	3.430	0.482	0.654	0.279	1.416	0.464	0.667	0.289	1.420
Manganese	0.076	1.007	0.038	1.121	0.079	1.046	0.046	1.171	0.075	0.673	0.056	0.804	0.032	0.680	0.059	0.771
Zinc	0.197	0.330	0.104	0.631	0.206	0.348	0.101	0.655	0.163	0.276	0.106	0.545	0.180	0.293	0.113	0.586
Copper	0.042	0.097	0.051	0.190	0.049	0.103	0.055	0.207	0.019	0.101	0.068	0.188	0.020	0.111	0.060	0.190
Boron	0.184	0.013	0.048	0.245	0.172	0.014	0.046	0.232	0.226	0.014	0.012	0.252	0.232	0.014	0.013	0.259
Treatment T_7																
Nitrogen	86.93	87.86	55.87	230.66	87.10	86.42	57.74	231.26	56.82	81.16	85.49	223.47	56.98	95.42	88.63	241.03
Phosphorus	13.30	13.61	12.62	39.53	14.18	13.99	12.76	40.93	13.07	13.62	5.80	32.49	13.68	14.22	7.43	35.33
Potassium	171.27	156.91	67.18	395.36	138.13	192.42	67.47	398.02	67.40	126.21	17.96	211.57	104.18	138.89	18.67	261.74
Sulphur	18.23	6.46	12.57	37.26	19.77	8.07	11.52	39.36	11.72	5.52	3.07	20.31	11.27	6.67	3.31	21.25
Calcium	79.61	18.93	52.66	151.20	102.30	19.50	53.59	175.38	71.79	13.23	14.39	99.41	81.54	12.66	15.27	109.46
Magnesium	3.827	9.04	14.73	27.60	4.444	8.97	15.58	29.00	3.545	9.71	7.649	20.90	3.908	10.13	7.023	21.07
Iron	0.247	0.598	2.842	3.687	0.279	0.599	2.806	3.685	0.537	0.630	0.314	1.481	0.590	0.650	0.332	1.572
Manganese	0.064	1.015	0.043	1.122	0.073	1.031	0.049	1.153	0.031	0.672	0.056	0.759	0.062	0.630	0.059	0.751
Zinc	0.223	0.370	0.112	0.705	0.216	0.395	0.115	0.726	0.161	0.347	0.103	0.611	0.185	0.337	0.111	0.633
Copper	0.027	0.100	0.052	0.179	0.033	0.110	0.057	0.200	0.021	0.118	0.058	0.197	0.024	0.132	0.061	0.217
Boron	0.271	0.010	0.053	0.334	0.255	0.007	0.054	0.316	0.189	0.010	0.016	0.215	0.268	0.010	0.017	0.295

Continue:

Nutrients	Nutrient Uptake (kg ha^{-1})															
	Sara Series								Gopalpur Series							
	Y-1				Y-2				Y-1				Y-2			
	Jute	T. aman	Mustard	Total	Jute	T. aman	Mustard	Total	Jute	T. aman	Lentil	Total	Jute	Jute	T. aman	Total
Treatment T_8																
Nitrogen	49.66	95.86	70.47	215.99	49.35	106.31	70.45	226.11	54.09	84.42	95.17	233.68	55.52	98.12	100.73	254.37
Phosphorus	12.94	17.32	13.89	44.15	13.44	15.37	14.13	42.94	19.11	16.79	6.54	42.44	20.02	16.82	7.92	44.76
Potassium	148.35	168.35	72.67	389.37	74.86	203.46	71.90	350.22	91.23	129.26	18.23	238.72	160.54	165.90	18.74	345.18
Sulphur	18.39	7.58	13.81	39.78	18.71	8.99	12.22	39.92	14.90	6.82	3.52	25.24	13.78	7.87	3.69	25.34
Calcium	81.20	14.46	58.57	154.23	84.24	14.61	57.04	155.88	90.14	19.58	17.01	126.73	124.63	17.85	18.44	160.91
Magnesium	4.379	11.23	16.29	31.89	4.313	10.25	16.33	30.89	3.965	11.38	8.377	23.72	4.982	11.43	7.849	24.26
Iron	0.237	0.696	3.075	4.008	0.257	0.675	3.020	3.951	0.512	0.758	0.353	1.624	0.578	0.752	0.367	1.697
Manganese	0.085	1.111	0.047	1.243	0.094	1.114	0.058	1.266	0.063	0.905	0.061	1.029	0.066	0.895	0.066	1.027
Zinc	0.169	0.402	0.141	0.712	0.231	0.434	0.138	0.803	0.185	0.363	0.122	0.670	0.200	0.396	0.130	0.726
Copper	0.027	0.117	0.056	0.200	0.011	0.127	0.061	0.199	0.040	0.123	0.070	0.233	0.048	0.126	0.074	0.248
Boron	0.322	0.018	0.059	0.399	0.388	0.019	0.061	0.468	0.288	0.013	0.018	0.319	0.316	0.013	0.018	0.347
Treatment T_9																
Nitrogen	80.80	99.61	90.11	270.52	79.87	109.83	93.41	283.11	70.61	84.59	85.20	240.40	71.63	98.16	91.88	261.67
Phosphorus	10.75	16.23	15.27	42.25	11.76	14.43	15.34	41.53	13.63	14.78	6.16	34.57	14.27	14.37	7.39	36.03
Potassium	153.77	166.90	80.35	401.02	121.61	206.34	82.77	410.72	123.20	131.59	16.25	271.04	136.82	141.13	16.70	294.65
Sulphur	17.87	9.10	15.83	42.80	18.32	9.99	14.77	43.08	13.73	6.88	3.59	24.20	13.01	7.89	3.83	24.73
Calcium	86.22	30.30	66.35	182.87	109.68	33.60	71.00	214.28	80.53	18.29	14.72	113.54	95.04	18.34	15.26	128.64
Magnesium	4.957	10.19	18.07	33.22	5.304	12.97	19.85	38.13	3.625	11.50	8.169	23.29	3.908	11.43	7.666	23.00
Iron	0.188	0.741	3.318	4.248	0.229	0.726	3.333	4.289	0.480	0.715	0.337	1.532	0.507	0.734	0.356	1.597
Manganese	0.060	1.370	0.059	1.489	0.062	1.372	0.069	1.503	0.058	0.940	0.070	1.068	0.063	0.965	0.073	1.100
Zinc	0.158	0.445	0.160	0.763	0.261	0.476	0.170	0.907	0.166	0.376	0.118	0.660	0.178	0.410	0.128	0.716
Copper	0.043	0.119	0.065	0.227	0.052	0.126	0.073	0.251	0.049	0.130	0.069	0.248	0.057	0.135	0.078	0.270
Boron	0.249	0.015	0.069	0.333	0.278	0.016	0.064	0.358	0.195	0.012	0.020	0.227	0.212	0.011	0.020	0.243

Continue:

Nutrients	Nutrient Uptake (kg ha^{-1})															
	Sara Series								Gopalpur Series							
	Y-1				Y-2				Y-1				Y-2			
	Jute	T. aman	Mustard	Total	Jute	T. aman	Mustard	Total	Jute	T. aman	Lentil	Total	Jute	Jute	T. aman	Total
Treatment T_{10}																
Nitrogen	51.68	82.06	65.18	198.92	48.11	85.02	54.52	187.65	38.17	77.53	70.85	186.55	38.39	91.82	65.65	195.86
Phosphorus	10.62	12.51	13.64	36.77	9.70	11.39	13.72	34.81	12.21	13.80	5.06	31.07	12.96	14.06	5.81	32.83
Potassium	88.30	152.48	64.27	305.05	70.84	160.42	57.28	288.54	90.66	134.39	14.21	239.26	125.17	123.36	14.85	263.38
Sulphur	12.96	6.81	9.97	29.74	13.41	8.76	8.70	30.87	12.77	6.46	2.13	21.36	11.02	7.03	2.29	20.34
Calcium	64.56	21.37	39.72	125.66	69.87	21.86	36.78	128.50	70.84	14.14	12.52	97.50	93.81	15.40	13.37	122.59
Magnesium	2.179	9.71	14.65	26.55	1.735	9.07	14.30	25.10	2.467	10.40	7.350	20.21	3.145	11.81	6.136	21.09
Iron	0.136	0.529	2.750	3.414	0.146	0.516	2.698	3.360	0.426	0.634	0.255	1.316	0.421	0.642	0.269	1.332
Manganese	0.032	1.081	0.045	1.157	0.033	1.091	0.048	1.171	0.028	0.671	0.044	0.743	0.045	0.671	0.047	0.763
Zinc	0.182	0.337	0.104	0.623	0.263	0.379	0.114	0.756	0.142	0.288	0.100	0.530	0.157	0.349	0.108	0.614
Copper	0.054	0.089	0.051	0.194	0.061	0.099	0.051	0.211	0.018	0.102	0.045	0.165	0.026	0.109	0.048	0.184
Boron	0.137	0.014	0.053	0.204	0.129	0.015	0.048	0.192	0.177	0.015	0.015	0.207	0.190	0.015	0.015	0.220

Y-1: Year-1; **Y-2:** Year-2

T_0 : Control;

T_1 :Farmers' practice;

T_2 : Farmers' practice + recom. S&B;

T_3 : Farmers' practice (75%) + recom. S&B (75%) + cow dung (5 t ha^{-1});

T_4 : Farmers' practice (75%) + recom. S&B (75%) +recom. poultry manure (3 t ha^{-1});

T_5 : Farmers' practice (75%) + recom. S&B (75%) + recom. oilcake (2 t ha^{-1});

T_6 :Recom. fertilizer nutrients;

T_7 :Recom. fertilizer nutrients (75%) + cow dung (5 t ha^{-1});

T_8 :Recom. fertilizer nutrients (75%) + recom. poultry manure (3 t ha^{-1});

T_9 :Recom. fertilizer nutrients (75%) + recom. oilcake (2 t ha^{-1}); and

T_{10} : Soil analysis based treatment