EFFECTS OF NAPHTHALENE ACETIC ACID AND SOWING TIME ON FERTILIZER USE EFFICIENCY AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.)

A
DISSERTATION
SUBMITTED TO THE UNIVERSITY OF DHAKA
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN
BOTANY
(PLANT PHYSIOLOGY, BIOCHEMISTRY AND PLANT NUTRITION)

By

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JULY 2019

DEDICATED

To

MY BELOVED PARENTS

DECLARATION

I do hereby declare that the work presented in this dissertation entitled **"Effects of Naphthalene acetic acid and sowing time on fertilizer use efficiency and yield of wheat (*Triticum aestivum* L.)"** is the original result of my own investigation. I further declare that this dissertation has been composed by myself and no part of this thesis has been submitted anywhere in any form for any academic degree. All sources of information have been specifically acknowledged by referring to the authors.

July 2019 **(A. M. M. Golam Adam)**

CERTIFICATE

*This is to certify that the research work and results of this dissertation entitled **"Effects of Naphthalene acetic acid and sowing time on fertilizer use efficiency and yield of wheat (Triticum aestivum L.)"** is the outcome of original work carried out by A . M. M. Golam Adam at the Botanical Garden of the Department of Botany, Plant Physiology, Biochemistry and Plant Nutrition Laboratory, Department of Botany, Research Laboratory of the Department of Soil, Water and Environment, University of Dhaka and also in the Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, under our joint supervision.*

This is further certified that this dissertation is suitable for submission in fulfilment of the requirements for the Degree of Doctor of Philosophy in Botany (Plant Physiology, Biochemistry and Plant Nutrition).

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ACKNOWLEDGEMENT

All praises belong to the almighty Allah, the most Merciful, Beneficent and Gracious, who enabled the author to complete the dissertation.

The author wishes to express his profound respect, heartiest sense of gratitude and sincere admiration to his supervisors, Prof. (Retd.) Dr. Nargis Jahan and Prof. Dr. Parveen Rashid, Plant Physiology, Biochemistry and Nutrition Laboratory, Department of Botany, University of Dhaka for professional supervision, scholastic guidance, constructive criticism, encouragement, affection and whole hearted co-operation during the course of investigation and also during write up of the thesis, without which, this work could have never been made successful.

The author would like to express his deep sense of gratitude to his teacher, Prof. Dr. Quazi Abdul Fattah for his valuable suggestion and continuous inspiration. The author is grateful to Prof. Dr. Md. Abul Bashar, former Chairman, Department of Botany, University of Dhaka, for his sympathy, suggestion, inspiration and Departmental facilities to carry out this investigation.

The author is also grateful to Prof. Dr. Sirajul Hoque, former Chairman, Department of Soil, Water and Environment, University of Dhaka, for giving permission to utilize his laboratory facilities for doing the part of biochemical analysis.

The author would like to express his profound gratitude to Prof. Dr. Rakha Hari Sarker, Chairman, Department of Botany, University of Dhaka and all other respected teachers of the Department of Botany, University of Dhaka, for their suggestion and continuous inspiration to carry out this investigation. The author is delighted to thank Md. Saiful Islam, Lecturer, Department of Botany, University of Dhaka for his nice cooperation and continuous encouragement all over the investigation period.

Sincere thanks and gratitude are due to University Grants Commission of Bangladesh for awarding UGC Ph.D fellowship and to the Jagannath University for allowing study leave to carry out this research.

The author is pleased to thank Dr. Md. Mahbubar Rahman , Umma Fatema Shahjadee and Dr. Md. Moniruzzaman, Senior Scientific Officers, BCSIR Laboratory, Dhaka for their cooperation during the biochemical analysis. Thanks are also to Bangladesh Agricultural Research Institute (BARI) for providing wheat seeds as research material.

The author is indebted to his parents, sisters, father-in-law, mother-in-law, family members, relatives and well wishers for their invaluable affection, inspirations, encouragement, sacrifice and moral support during the course of this research work.

The author is very much pleased to his beloved wife, Wadia Shabab for her love, care, assistance, affection, continuous inspirations and invaluable sacrifice for completion of this dissertation. Last but not the least, the author is really indebted to his daughter, Waqida Risvana Aniyah for her coming as a blessings.

The Author

ABBREVIATIONS AND UNITS

Abbreviations

AOAC	Association of Analytical Chemists
BARI	Bangladesh Agricultural Research Council
BCSIR	Bangladesh Council of Scientific and Industrial Research
BY	Biological yield
Ca	Calcium
Chl. a	Chlorophyll a
Chl. b	Chlorophyll b
cv.	Cultivar
DAS	Days after sowing
et al.	*et alibi* (and others)
etc.	et cetra (and so on)
EY	Economic yield
Fe	Iron
Fig.	Figure
FUE	Fertilizer use efficiency
GDP	Gross Domestic Product
HI	Harvest index
HYV	High yielding variety
ICRISAT	International Crop Research Institute For Semi-arid Tropics
IFIA	International Fertilizer Industry Association
IFPRI	International Food Policy Research Institute
K	Potassium
N	Nitrogen
NAA	Naphthalene acetic acid
NUE	Nitrogen use efficiency
P	Phosphorus
PGR	Plant growth regulator
RBD	Randomized Block Design
TDM	Total dry matter
viz.	Videlicet (namely)
Zn	Zinc

Units

µg	Microgram
cm	Centimeter
dS/m	deciSiemens per metre
g	Gram
ha	Hectare
kg	Kilogram
L	Liter
M	Mole
mµ	Millimicron
meq	Milliequivalent
mg	Milligram
ml	Milliliter
ppm	Parts per million
t	Ton
^{o} C	Degree Celsius
%	Percentage

Supporting publication

1. Adam AMMG and Jahan N 2019. Effects of sowing time on growth and yield performance of six high yielding varieties of wheat (*Triticum aestivum* L.). Bangladesh J. Bot. **48**(1): 43-51.

ABSTRACT

The present research work was mostly carried out in the Plant Physiology, Biochemistry and Plant Nutrition Laboratory of the Department of Botany and partly in the Department of Soil Water and Environment, University of Dhaka and also in Bangladesh Council of Scientific and Industrial Research (BCSIR) to study the effect of Naphthalene acetic acid (NAA) and sowing time on wheat (*Triticum aestivum* L.). The investigation consists of recording and estimating different physiological and biochemical parameters through which yield was affected and finally to evaluate the fertilizer use efficiency (FUE) by wheat plants.

In the course of present investigation four field experiments were carried at the Botanical Garden of the Department of Botany, University of Dhaka for three consecutive years during the period from 2014 to 2017. First experiment was conducted with six high yielding varieties of wheat (var. BARI Gom-23, BARI Gom-24, BARI Gom-25, BARI Gom-26, BARI Gom-27 and BARI Gom-28) in four sowing time (November 15, November 22, November 29 and December 04) during 2014-2015 season for selection of the best performed variety and optimum sowing time. Second experiment was carried out in selected optimum time (November 15) of 2015-2016 using different concentrations of NAA (0, 10, 20, 30, 40, 50 and 60 ppm) as foliar spray in combination with various Nitrogen (N) levels (0%, 25%, 50%, 75% and 100% of the recommended dose) on the selected variety of wheat (BARI Gom-25). Third experiment was also carried out during 2015-2016 in selected optimum time with lower concentrations of NAA (0, 10, 20 and 30 ppm) as seed soaking treatment in combination with the recommended dose of N-fertilizer on the selected variety. During 2016-2017 fourth experiment was carried out using best foliar and seed soaking treatments in combination with varying N-levels at two sowing time (timely and 7 days late sown).

Results obtained during 2014-2015 season revealed that the maximum plant height was recorded from BARI Gom-24 at most of the ages and seed sown on November 29 produced tallest plant all over the ages whereas, December 04 sown wheat produced the shortest plant in BARI Gom-28 from 75 days after sowing (DAS) up to harvest. Results also revealed that seeds sown on November 15 produced the

highest number of tillers, leaves and total dry matter (TDM) per plant in BARI Gom-25 with few exceptions. Yield contributing characters *viz.* number of grains per plant, dry weight of spike, 1000-grain weight, yield per plant and hectare and harvest index were recorded maximum from BARI Gom-25. November 15 sown wheat resulted maximum values in all yield contributing parameters with significant responses except the number of non-effective tillers per plant. Combined effects of variety and sowing time showed that November 15 sown BARI Gom-25 also resulted maximum number of effective tillers per plant (8.13), number of grains per plant (236.79), dry weight of spike (24.17 g), 1000-grain weight (50.64 g), yield per plant (11.99 g) and per hectare (6.00 t) and harvest index (30.92%) where, it was significantly higher than rest of the treatments in case of dry weight of spike, 1000-grain weight, yield per plant and per hectare.

Results obtained from the second experiment during 2015-2016 revealed that foliar spray of NAA and N-fertilizer had mostly stimulatory responses on plant height where, full dose of N-fertilizer without foliar NAA produced maximum plant height throughout the ages. Number of tillers per plant of BARI Gom-25 was non-significantly affected by NAA treatments whereas, higher doses of N-fertilizer produced higher number of tillers per plant all over the ages. Spraying of 20 ppm NAA in combination with full doses of N-fertilizer although produced higher number of tillers per plant than all other combination treatments but statistically not different from some other treatments including 20 ppm in combination with 25% N-fertilizer.

Application of NAA treatments had mostly non-significant responses on the number of leaves of BARI Gom-25 whereas, different levels of N-fertilizers produced significantly higher number of leaves per plant at most of the ages. Number of leaves per plant noted at harvest from full dose of N-fertilizer without any NAA was significantly higher than all other combinations except 75% N-fertilizer without NAA. The TDM per plant were positively influenced following application of NAA and N-fertilizer and also by their combinations at most of the ages. Application of 20 ppm NAA in combination with full doses of fertilizer although resulted highest TDM per plant but statistically not different from 20 ppm NAA in combination with 25% fertilizer dose at most cases. Findings also indicated that 20 ppm NAA in combination with 25% fertilizer resulted higher TDM than full dose of fertilizer alone.

Spraying of 20 ppm NAA had resulted maximum number of effective tillers per plant, length of spike, number of grains per spike and per plant, dry weight of spikes, yield per plant and per hectare but with statistically identical value to rest of the treatments. Different doses of N-fertilizer although produced higher number of effective tillers per plant, number of grains per plant, dry weight of spikes, yield per plant and per hectare but were statistically at par to each other.

Results obtained from combined application of NAA and N-fertilizer showed that combination of 20 ppm NAA and full dose of N-fertilizer although resulted maximum number of effective tillers per plant but statistically identical to many other combinations with lower doses of fertilizer including 20 ppm NAA at 25% N-level. Number of non-effective tillers per plant was influenced non-significantly due to all combined treatments. Application of 20 ppm NAA at 25% N-level had resulted maximum length of spike (9.13 cm) and number of grains per spike (35.13). Results also showed that number of grains per plant (115.92), dry weight of spike (7.07 g), yield per plant (5.26 g) and per hectare (2.63 t) obtained from 20 ppm NAA at 25% N-level were statistically not different from other combined treatments including 20 ppm NAA in combination with full dose of N-fertilizer. Yield per plant increased by 107.28 and 101.53% due to 20 ppm NAA in combination with full dose of N-fertilizer and in combination with 25% N-fertilizer respectively. The maximum harvest index (43.18%) was noted from 40 ppm NAA in combination with 50% N-level which was statistically similar to control.

Findings showed that spraying of NAA treatments resulted significantly higher chlorophyll a (chl. a) and carotenoids contents of leaves at tillering stage with few exceptions. Application of 50, 75 and 100% of the recommended N-fertilizer produced significantly higher chl. a content at all stages *viz.* tillering, flowering and grain filling and carotenoids content at tillering stage in majority of cases. Combination of NAA and fertilizer had significant influences upon pigment contents of leaves at all stages except chl. b content at grain filling stage.

Outcome of experiment 3 conducted during 2015-2016 revealed that seed soaking with 10 ppm NAA in combination with recommended N-fertilizer produced better stimulations in plant height, number of tillers, number of leaves and TDM per plant with significant variations in majority of cases. Number of effective tillers per plant (5.75), number of grains per plant (185.48), dry weight of spikes (9.23 g), yield per plant (8.23 g) and per hectare (4.12 t) were recorded maximum from seed soaking with 10 ppm NAA in combination recommended N-fertilizer treatment and were significantly higher than control in case of number of effective tillers per plant, number of grains per plant and yield per plant and per hectare. Results showed that yield per plant increased by 16.08 and 13.68% following seed soaking with 10 ppm and 20 ppm NAA in combination recommended dose of N-fertilizer respectively. However yield per plant due to seed soaking with 30 ppm NAA in combination with recommended N-level reduced by 8.85%. Significantly higher pigment content of leaves both at tillering and grain filling stages were also obtained from 10 ppm NAA with recommended dose of N fertilizer treatment.

In the fourth experiment, during 2016-2017 season, seed soaking with 10 ppm NAA in combination with 75% N-fertilizer resulted taller plant, maximum number of tillers and leaves per plant in most of the growth ages at both timely and late sown condition where, it were significantly higher than the most of treatments. Results revealed that late sown wheat produced comparatively taller plant than timely sown. However, timely sown wheat produced higher number of tillers per plant than late sown condition but statistically at par with full dose of N-fertilizer alone and in combination with 10 ppm seed soaking treatment. Seed soaking with 10 ppm NAA in combination with 75% N-fertilizer also produced maximum dry matter per plant throughout the growth ages at both sowing time where it was significantly higher than all other treatments including full dose of N-fertilizer.

Seed soaking with 10 ppm NAA in combination with 75% N-fertilizer resulted maximum values on various yield parameters and yield of BARI Gom-25 at both timely and late sown condition with few exceptions. In case of timely sown BARI Gom-25, number of grains per plant (198.08), dry weight of spikes (16.54 g), 1000-grain weight (45.80 g), yield per plant (7.75 g) and per hectare (3.88 t) recorded from seed soaking with 10 ppm NAA in combination with 75% N-fertilizer (best performed treatment) were significantly higher than the majority of treatments including full dose of N-fertilizer. Yield per plant of timely and late sown BARI Gom-25 obtained from the best performed treatment were 24.80 and 19.24% higher than that of recommended dose of N-fertilizer. Results also indicated that yield per plant reduced by 5.56% at 7 days late sowing.

The best performed treatment had also significant beneficial effect on different biochemical components *viz.* leaf pigments, nutrient uptake, nitrogen use efficiency, nutritional value, enzyme activities, amino acid and mineral contents. Findings revealed that the best performed treatment with few exceptions produced significantly higher pigment contents than full dose of N-fertilizer at all stages in both timely and late sown condition. Nitrogen (N), phosphorus (P) and potassium (K) contents of shoot, root and grain were affected significantly following all treatments at all stages *viz.* flowering, grain filling and harvest in both sowing time. Significantly maximum NPK uptake by shoot, root and grain was also obtained from the best performed treatment at flowering and harvest stages in majority of cases of both sowing time. At grain filling stage, the best performed treatment also resulted significantly higher NPK uptake than full dose of N-fertilizer in both cases except uptake by root of timely sown wheat. Nitrogen use efficiency (NUE) due to NAA at varying N levels were significantly higher than full dose of fertilizer in most cases at both sowing time.

During 2016-2017 season, considering yield performances, three treatments (control, 100% of recommended dose of N-fertilizer and best performed treatment) of timely sown BARI Gom-25 were selected for comparative analysis on some nutritional parameters, amino acid contents, enzyme activities and mineral contents of grain. Results showed that the best performed treatment produced significantly higher amount of protein (17.81%), starch (52.69%), total ash (1.96%), total sugar (5.65%) and reducing sugar (0.92%) contents than control and full dose of N-fertilizer treatment. Increase in starch, protein, total ash, total sugar and reducing sugar contents following the best performed treatment were 1.64, 2.65, 7.69, 1.25 and 10.84% higher over full dose of N-fertilizer respectively. Carbohydrate content following the best performed treatment was recorded higher than full dose of N-fertilizer. Although the maximum fat content (1.69%) was obtained from full dose of N-fertilizer but statistically at par to the best performed treatment. However, moisture content of grain decreased significantly due to both full dose and best performed treatments.

Amino acids *viz.* aspartic acid, serine, glutamic acid, glycine, alanine, valine, isoleucine, leucine, tyrosine, histidine, lysine and arginine were recorded maximum following the best performed treatment. In case of threonine (0.35%) and methionine (0.26%) in addition to the best performed treatment the maximum was also recorded from full dose of N-fertilizer treatment. Findings indicated that the amount of aspartic acid (0.74%), glutamic acid (3.71%), leucine (0.88%), lysine (1.01%) and arginine (1.89%) recorded were significantly higher than both control and full dose of N-fertilizer treatments, whereas, those of serine, glycine, valine, isoleucine, tyrosine and histidine are statistically not different from full dose of N-fertilizer treatment. Amino acids *viz*. aspartic acid, serine, glutamic acid, glycine, alanine, valine, isoleucine, leucine, tyrosine, histidine, lysine and arginine increased by 2.78, 1.82, 2.77, 3.92, 2.08, 3.70, 2.33, 3.53, 3.45, 2.94, 3.06 and 2.16% over F_4 treatment respectively.

Enzyme activities of grain were positively influenced by different treatments where, significantly higher α-amylase content was recorded from the best performed treatment. Increases in α-amylase and protease activities following the best performed treatment were 23.08 and 27.27% over control and 6.67 and 9.80% over full dose of N-fertilizer treatment respectively. Mineral *viz.* N, K, Fe and Ca contents were also noted maximum from the best performed treatment and in case of Ca it was significantly higher than control and full dose of N-fertilizer. However, the amount of P and Zn was obtained maximum from full dose of N-fertilizer whereas, in case of P content it was not significantly different from that of best performed treatment.

Findings indicated that NAA had beneficial effect on growth and yield of BARI Gom-25 when applied as seed soaking treatment rather than foliar spray. Seed soaking with 10 ppm NAA and applying 25% less urea, the yield of timely sown wheat could be increased up to 24.80%. By reducing the demand of nitrogen fertilizer up to 25%, this best performed treatment not only increase the yield of wheat but remarkably improved the quality of grain. From the cost benefit analysis, it was also revealed that seed soaking with 10 ppm NAA at 75% N-level treatment could add 17,500 Taka more benefit in per hectare area. Thus, use of 10 ppm NAA as seed soaking treatment is economically advantageous and could be used in farmer level for higher production of wheat.

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INTRODUCTION

Bangladesh is predominantly an agrarian country and agriculture sector contributes about 17% to the country's Gross Domestic Product (GDP) and employs more than 45% of total labour force (Yearbook of Agricultural Statistics 2015). Cereal grains have been the principal component of human diet for thousands of years and have played a major role in shaping human civilization. More than 50% of world daily caloric intake of billions people is derived directly from cereal grain consumption (Awika *et al*. 2011).

Wheat (*Triticum aestivum* L.) has a prominent position among the cereals that supplement nearly one-third of the world population's diet by providing half of the dietary protein and more than half of the calories (Dhanda *et al.* 2004). The per capita consumption of wheat flour varies widely by region. Developing countries use more than 80% of their wheat supply for making food compared to developed countries that use less than 50% (Anon 2003).

Wheat is a major diet component because of the plant's agronomic adaptability, ease of grain storage and ease of converting grain into flour for making edible, palatable, interesting and satisfying foods. Doughs produced from bread wheat flour differ from those made from other cereals in their unique viscoelastic properties (Orth and Shellenberger 1988). Moreover, wheat cultivation is easier and requires less time and irrigation than other alternative crops like rice, legumes, and potatoes; additionally it has low cultivation costs.

In Bangladesh, wheat is the second major cereal crop after rice, but rice alone is no more capable of providing balanced and nutritious food for the human, poultry, and livestock. It is a major source of a number of essential amino acids and its protein content is higher than either rice or maize. The whole grain contains approximately: water 13%, protein 11.5-12%, fat 1.72-2.0 %, carbohydrate 69.60-70%, fibre 2% and ash 1.5-2% (Purseglove 1975). It also contains minerals 27.20 g, calcium 48 mg, phosphorus 426 mg, iron 3.20 mg, thiamin 0.49 mg, riboflavin 0.29 mg, niacin 4.40 mg, vitamin A 29.20 mμ. Wheat protein is easily digested by nearly 99% of human population, the exception being the 1% with gluten sensitivity. The sufficient quantity of wheat can improve the nutrition situation in the country (Wadud *et al.* 2001). It is also a popular source of animal feed, particularly in years where harvests are adversely affected by rain and significant quantities of the grain are made unsuitable for food use. Such low-grade grain is often used by industry to make adhesives, paper additives, several other products and even in the production of alcohol.

The Population Action International, a nongovernmental organization, stated that the world's population is growing eight times faster than arable land and at least 17 countries will face food scarcity by the year 2025, including Bangladesh. In the next century at least 3 billion more people will have to be fed on the same amount of farmland that is becoming degraded (Caruso 1995). The International Food Policy Research Institute (IFPRI) projections indicated that the world demand for wheat will rise to 775 million metric tons by 2020, and 60 % in total by 2050. At the same time, climate change-induced temperature increases are likely to reduce wheat production in developing countries where around 66 % of all wheat is produced (Rosegrant and Agcaoili 2010). The density of the Bangladesh population is much higher than any other mega country (Streatfield and Karar 2008). In addition, the problem of land scarcity is being compounded day by day as there is no scope for bringing new land under cultivation.

Increasing food production of the country in the next 20 years is a big challenge. Currently about 1.4 million metric tons of wheat is being produced in Bangladesh against the national demand of 5.6 million metric tons and the country needs to import about 4.5 million metric tons wheat every year (Azad *et al.* 2017). As a result, there is always pressure to harvest higher wheat yields to feed the burgeoning population. The average yield of wheat in Bangladesh is very low in compared to other leading wheat growing countries like Netherland, UK, France, Norway etc. Low quality seed, salinity, water logging, inadequate use of fertilizers, lack of irrigation water, high input prices, low farmers' education and no use of micronutrients and organic fertilizers are the major reasons for low wheat production (Khan *et al*. 1999).

The yield of wheat could be achieved through a number of agronomic techniques where, selection of high yielding variety, optimum sowing time, application of plant growth regulators and proper use of fertilizers needs due attention. Variety plays an important role in producing high yield of wheat because different varieties responded differently for the genotypic characters, input requirement, growth process and the prevailing environment during growing season (Sultana *et al*. 2012). Each variety has a genotype-specific ability to maintain performance over a wide range of environmental conditions (Hancock 2004). This ability is usually referred to as the sensitivity or adaptability of a variety. Such ability is an important property, because farmers naturally want to use varieties which perform well in their own fields (Bajaj 1990).

Findings of various investigations also revealed that sowing time had marked effect on growth and yield of wheat varieties (Singh and Uttam 1999, Kumar *et al.* 2000, Shah and Akmal 2002, Subhan *et al.* 2004, Akhtar *et al.* 2006, Abdullah *et al.* 2007, Shahzad *et al.* 2007, Ali *et al.* 2010, Baloch *et al.* 2010). Zia-ul-Hassan *et al*. (2014) reported that wheat yield is far below than the potential yield due to many factors of which sowing time being most important. Optimum time for wheat is very important due to its own definite requirements for temperature and light for emergence, growth and flowering (Dabre *et al.* 1993). Too early sowing produces weak plants with poor root systems. Again, late sowing of wheat is a major problem in the rice wheat areas of Asia (Hobbs and Gupta 2002). In late sown wheat, all the growth stages, such as tillering, flowering, and grain filling are adversely affected by the shortened growing period. The reduction in the optimum growth period caused by a rise in temperature leads to leaf senescence resulting in a photosynthetic rate that is too low to meet plant C-economy (Sharma-Natu *et al*. 2006). As a result, it affects two important yield parameters *viz.* number of grains per spike and grain weight (Ugarte *et al*. 2007). After optimum sowing time, production of wheat decreases about 18 kg/ha for each day (Saifuzzaman *et al.* 2010). During the course of this investigation an attempt will be made for the selection of the best variety depending on their growth and yield response to sowing times.

Application of chemical fertilizers has played a pivotal role in increasing crop production all over the world as they constitute an integral part of improved crop production technology (Saifullah *et al*. 2002). Inorganic and organic fertilizers are applied to maintain the nutritional condition of different cropping systems.

Rationalizing fertilizer application is an important issue for sustainable agriculture because it can reduce the negative effects of farming on the surrounding environment (Zebarth *et al*. 2009). An agricultural system should include yield and environmental quality during management. The proper amount of fertilizer application is considered a key to the bumper crop production (Tariq *et al.* 2007). It is well known that balanced fertilization helps efficient utilization of other agricultural inputs and increases crop yields (Alam *et al.* 2000). But, farmers in our country generally do not use the recommended doses of fertilizers. Only 50 % of the farmers use recommended doses of organic and inorganic fertilizers (Saifuzzaman *et al.* 2010).

Among the chemical fertilizers, nitrogen (N) is major factor limiting yield of wheat (Andrews *et al.* 2004). It is required by plants in comparatively larger amounts than the other essential nutrients. All vital biological processes are related to the existence of functional plasma, of which N is a basic constituent (proteins, nucleic acids). It is also a basic constituent of many other compounds of primary physiological importance to plant metabolism, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins (Marschner 1995). The amount of N fertilizer applied to plants must be carefully managed to ensure that N will be available throughout the growing season, and vegetative and reproductive development will not be restricted (Vidal *et al.* 1999). Availability of N has impacts throughout crop development, affecting seedling establishment, tillering, canopy development as well as grain filling, all of which have the potential to influence final yield and together determine the N requirements of the crop.

Fertilizer use efficiency (FUE) is an important factor that needs to be taken into consideration in agricultural production systems. Generally, fertilizer use efficiency by crops is in the range of 50-70% for N, 10-25% for P and 50-60% for K (IFIA 1992, 1999). Analysis and interpretation of Moll *et al.* (1982) showed three main controllable factors that reduce fertilizer use efficiency are unbalanced fertilization (20-50% reduction), inappropriate crop variety (20-40% reduction) and untimely sowing (20-40%).

Usually crops are often fertilized with large amounts of N-fertilizer, but only a small fraction of this (roughly 5-50%) is taken up by the plants (Carranca 2012).

Applied N not taken up by the crop or immobilized in the soil is lost by volatilization, denitrification, leaching and runoff (Canfield *et al.* 2010). In addition, excessive fertilizer use is proven to cause a number of environmental and ecological problems within and outside of farmlands *viz.* air pollution, soil acidification and degradation, water eutrophication, crop yield reduction etc. (Vitousek *et al.* 2009, Sutton *et al.* 2011, Lu and Tian 2013). The N losses can be reduced by enhancing the plants' N uptake efficiency, which greatly affects the overall nitrogen use efficiency (NUE) of a crop. Moreover, higher NUE by plants could reduce fertilizer input costs, decrease the rate of nutrient losses and enhance crop yields.

Simons (1982) and Alley *et al.* (1999) showed that nitrogen fertilizer rate and timing are the major tools available after planting for manipulating wheat growth and development to produce a greater grain yield per unit area. Reports regarding the effects of N fertilizer on growth, yield, grain quality, NUE, protein content, photosynthetic pigments, carbohydrate content are available from all over the world (Warraich *et al.* 2002, Guarda *et al.* 2004, Bavec *et al.* 2007, Tranaviciene *et al.* 2007, Jermuss and Vigovskis 2008, Khan *et al.* 2008, Makowska *et al.* 2008, Abedi *et al.* 2011, Ali *et al.* 2011, Gharekand *et al.* 2012a and 2012b, Krobel *et al.* 2012, Dandan and Shi 2013, Gashaw *et al.* 2013, Leta *et al.* 2013, Samadiyan *et al.* 2013, Shahzad *et al.* 2013). Currently in different countries of the world the strategy is to maximize the production with minimum use of fertilizers and agrochemicals because of their harmful effects.

Plant growth regulators are organic substance other than nutrient, active in very minute amounts which are formed in certain parts of the plant and usually translocated to other sites, where it evokes specific physiological, morphological and biochemical responses. Deficiency of these growth regulators at any stage of plant growth may also creates a barrier in attaining maximum growth and yield. Investigators around the world found that yield of major cereal crops can be increased by the application of plant growth regulators. Available reports indicate that different plant growth regulators revealed stimulatory responses on wheat varieties (Singh and Gill 1985, Sentelhas *et al.* 1987, Sliman *et al.* 1994, Nasser and Ashraf 2001, Alam *et al.* 2002, Ahmed *et al.* 2004, Akman 2009, Ahmed *et al.* 2010, Akram *et al.* 2011, Kumar *et al*. 2011).

Research works on wheat on the effect of nitrogen fertilizer in combination with growth regulators have also been conducted in other countries (Mahmood *et al.* 2005, Mahmood *et al.* 2007, Shekoofa and Emam 2008).

In Bangladesh research has been done on wheat on various aspects *viz.* cultural method and varietal effect (Rahman *et al.* 2010), nitrogen fertilizer (Khaleque *et al.* 2008, Sadat *et al.* 2008, Rahman *et al.* 2011), growth regulators (Ahmed *et al.* 2010, Jahan and Adam 2013, Adam *et al.* 2016), growth regulator and fertilizer (Islam and Jahan 2016a and 2016b), sowing time (Rashid *et al.* 2004, Jahan and Adam 2015, Madhu *et al.* 2018), sowing time and variety (Uddin *et al.* 2015, Shaheb *et al.* 2016). Though investigations have shown that application of appropriate concentrations of NAA induce greater growth and yield of crop plants including wheat (Adam and Jahan 2011, Jahan and Adam 2011, Jahan and Adam 2013) but, reports elucidating the fertilizer use efficiency are lacking (Islam and Jahan 2016b).

No report is yet available on the responses of Naphthalene acetic acid (NAA) either as seed soaking or as foliar spray treatments in combination with different levels of nitrogen fertilizer on timely and late sown wheat. In addition, reports are also not available in this regards in other countries of the world. Thus the investigation was undertaken with the following objectives-

i) To select the best performed variety and its optimum time of sowing;

ii) To investigate the effects of NAA on different physiological, biochemical and yield parameters of the best performed variety at least to maintain the present level of yield by using lower dose/s of fertilizers;

iii) To evaluate

  (a) nitrogen use efficiency of both timely and late sown wheat due to selected treatments;
  (b) the qualitative changes in the grains due to selected treatments;

iv) To make a cost benefit analysis of the treatments on wheat.

REVIEW OF LITERATURE

2.1 Wheat

Wheat (*Triticum aestivum* L.) is a member of the family Poaceae (Gramineae), tribe Triticeae and in the subfamily Pooideae. Worldwide, two species of wheat are commonly grown, *T. aestivum* (bread wheat) and *T. turgidum* ssp. durum. Bread wheat is an allohexaploid (6x), which regularly forms 21 pairs of chromosomes (2n = 42) during meiosis. These chromosomes are subdivided into 3 closely related (homoeologous) groups of chromosomes, the A, B and D genomes. Each of these homoeologous groups normally contains 7 pairs of chromosomes (AABBDD). The 'A' genome was derived from einkorn wheat, *T. boeoticum* (*T. aegilopoides*) or *T. monococcum*. The 'B' genome donor is considered to be a wild and weedy grass (*Aegilops speltoides* or *A. searsii*). Whereas, the D genome was contributed by another wild and weedy grass *A. squarrosa* (*T. tauschii*). Besides, chromosome doubling, mutation and intercrossing of natural and human selection have helped in the development of different varieties (Gill 1979). Wheat Research Center of Bangladesh Agricultural Research Institute has already released 32 varieties of wheat.

Wheat has wide adaptability and can be grown in the tropical, sub-tropical and temperate zone. The crop grows most successfully between the latitudes of 30^0 and 60^0 North and between 27^0 and 40^0 South. It is grown in the world in rainfall ranges of 30-113 cm. The most favourable climatic condition for wheat cultivation is cool and moist weather during the vegetative growth period followed by dry, warm weather for the grain to mature and ripening. The optimum temperature range for ideal germination of wheat seed is 20-25 ^oC. Two seasonal forms of wheat are recognized, winter wheat and spring wheat. Under the warmer conditions, all wheats are winter grown. During the heading and flowering stages, excessively high or low temperatures and drought are harmful to wheat. Wheat plant requires about 25-30 ^oC optimum average temperature at the time of ripening. The temperature at the time of grain filling and development are very crucial for yield.

The mature wheat plant consists of a central stem from which leaves emerge at opposite sides. It is made up of repeating segments, called phytomers, which contain a node, a hollow internode, a leaf and a tiller bud found in the axil of the leaf. The leaf sheath wraps around the stem providing support to the shoot. The stem terminates in the spike of the wheat plant. Tillers are lateral branches which are produced off the main stem of the wheat plant. They produce leaves on opposite sides of their central stem in the same manner as the leaves of the main stem are produced and are also able to produce spike at their terminal. Not all tillers will survive and produce spike and this is thought to be due to competition for light and nutrients. The leaf structure consists of the sheath and the leaf blade which form from separate meristems. At the base of the leaf blade, where it joins the sheath, are a set of structures called the ligule and auricles. A mature wheat plant has two distinct root types. The seminal roots develop from the root primordia contained within the grain and are the first root type to emerge. The nodal roots emerge at the same time that tiller development starts. Inflorescence is a terminal cylindrical compound distichous spike, made up of two rows of spikelets. The spikelets contain the florets and are arranged on opposite sides of a central rachis. Grains are usually 2 per spikelet, oval with central groove on ventral surface. The caryopsis or grain of the wheat plant is made up of the bran coat and the endosperm surrounding the embryo The bran coat consists of three layers, the pericarp, testa and aleurone. The endosperm makes up 83% of the wheat grain. It stores the starch and protein important both for the developing plant and flour production. The embryo makes up only a small percentage of the grain but contains the root radicle and the shoot apex surrounded by the coleoptile. The scutellum separates the endosperm from the embryo (Purseglove 1975, Perry and Belford 2000, Kirby 2002).

2.2 Sowing time

Sowing time is an important determinant of crop yield. It depends on the onset of significant rainfall, temperature and humidity of a region. Determining suitable sowing time plays an important role in conformation of plant growth stages with desirable environmental conditions which results in maximum yield. Sowing time has a considerable effect on seed yield by influencing the yield contributing characters of crops. Manipulation of sowing time helps in minimizing the pest damage by producing asynchrony between plant and pest. Pathogens are able to infect susceptible plants under certain environmental condition. Results of several investigation showed that sowing time had marked effect on growth and yield of different varieties of wheat (Shah and Akmal 2002, Rashid *et al.* 2004, Subhan *et al.* 2004, Akhtar *et al.* 2006, Abdullah *et al.* 2007, Shahzad *et al.* 2007, Hussain *et al.* 2008, Ali *et al.* 2010, Baloch *et al.* 2010, Jahan and Adam 2015, Uddin *et al.* 2015, Madhu *et al.* 2018).

2.2.1 Effects of sowing time on physiological parameters

2.2.1.1 Plant height

Height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors (Shahzad *et al.* 2007). Hussain *et al.* (2008) while working on the effects of sowing dates (October 25, November 25 and December 25) on wheat cultivar ‘Inqulab-91’ found significant effect on plant height. They also found that plant height significantly decreased with delayed sowing. In order to optimize time of sowing of wheat variety ‘Hashim-8’ Baloch *et al.* (2010) conducted an experiment on five different sowing time (October 25, November 10, November 25, December 10 and December 25) with different seeding rates and reported that plant height of wheat differed significantly by planting time where, October 25 and November 10 produced the tallest plant but decreased subsequently with successive sowing dates. Madhu *et al.* (2018) evaluated the effect of four sowing date *viz.* November 15, November 30, December 15 and December 30 on four varieties of wheat (BARI Gom-25, BARI Gom-26, BARI Gom-27 and Shatabdi) and obtained significantly higher plant height from BARI Gom-25 when sown on November 15. They also reported that plant height decreased subsequently with successive sowing dates.

2.2.1.2 Number of tillers per plant

The economic yield of most of the cereals is determined by the number of tillers. Reports regarding the effect of sowing time on number of tillers are limited. Ansary *et al.* (1989) reported that delay sowing caused reduction in the number of tillers in wheat. Ejaz *et al.* (2002), Shivani *et al.* (2003) also reported that timely seeded wheat (November 21) produced more tillers. Findings of Baloch *et al.* (2010) revealed that out of five sowing time (October 25, November 10, November 25, December 10 and December 25), the maximum number of tillers per plant was obtained from October 25 and November 10 sown wheat although decreased subsequently with successive sowing dates. Jahan and Adam (2015) showed that sowing time had pronounced effect on the number of tillers per plant of BARI Gom-25 where November 14 sown wheat produced significantly maximum number of tillers than rest of the sowing time (November 24 and December 03) in most cases. Madhu *et al*. (2018) recorded significantly maximum number of total tillers per hill from BARI Gom-25 when sown on November 15 followed by November 30, December 15 and December 30 respectively.

2.2.1.3 Number of leaves per plant

The increase in leaf number is of vital importance for plants because of the physiological importance of leaf for photosynthetic activities. Till now, only one report has been made on the effect of sowing time on number of leaves per plant in wheat. Jahan and Adam (2015) evaluated the effect of three sowing time *viz.* November 14, November 24 and December 03 on BARI Gom-25 and counted maximum number of leaves per plant from November 14 sown in most of the growth ages.

2.2.1.4 Total dry matter per plant

Total dry matter (TDM) of a plant is an important parameter which influences the production of yield attributes and yield of plant. Literature regarding the effect of sowing time on total dry matter per plant on wheat is scanty. Research report of Hussain *et al*. (2008) revealed that October 25 sown wheat cultivar had significantly higher biological yield than those of November 25 and December 25. Findings also revealed that the minimum value was obtained from December 25.

2.2.2 Effects of sowing time on yield attributes and yield

2.2.2.1 Number of effective tillers (spikes) per plant

Research report revealed that earlier planting resulted in better spike development due to longer growing period (Warraich *et al*. 1981). Shahzad *et al*. (2007) reported that wheat sown on December produced significantly higher number of productive tillers than sown on November. Hussain *et al*. (2008) evaluated the effect of three sowing dates (October 25, November 25 and December 25) on wheat cultivar 'Inqulab-91' and reported that number of fertile tillers decreased linearly with successive delay in sowing from October 25 to December 25. Findings of Jahan and Adam (2015) revealed that November 24 sown BARI Gom-25 resulted significantly higher number of productive tillers than that sown on December 04. However, statistically similar number of productive tillers was noted from both November 14 and 24. Madhu *et al.* (2018) recorded significantly higher number of effective tillers per plant from November 15 sown BARI Gom-25 than rest of the sowing time *viz.* November 30, December 15 and December 30.

2.2.2.2 Number of non-effective tillers per plant

Published report regarding the effect of sowing time on non-effective tillers per plant is unavailable on any variety of wheat.

2.2.2.3 Length of spike

The length of spike plays a vital role in wheat towards the grains per spike and finally the yield (Shahzad *et al*. 2007). Literature relating to the effect of sowing time on length of spike is scanty. Baloch *et al*. (2010) reported that wheat sown on October 25 and November 10 produced the longest and statistically at par spike length but further delay in sowing resulted in shorter spike length. Madhu *et al.* (2018) evaluated the effect of four sowing time *viz.* November 15, November 30, December 15 and December 30) on four varieties of wheat *viz.* BARI Gom-25, BARI Gom-26, BARI Gom-27 and Shatabdi and found significant decreases in length of spike beyond the time of November 15. In fact, there is very meager published information available regarding the effect of sowing time on length of spike.

2.2.2.4 Dry weight of spike

No report is yet available on the effect of sowing time on dry weight of spike in wheat.

2.2.2.5 Number of grains per spike and per plant

Reports on the response of sowing dates on the number of grains per plant are limited for wheat. Hussain *et al*. (2008) reported that sowing dates had significant response on number of grains per plant. Wheat sown on October 25 produced significantly greater number of grains per spike than that sown on December 25 but statistically similar to November 25 sown wheat. Jahan and Adam (2015) also obtained the maximum number of grains per plant from November 24 sown BARI Gom-25 followed by November 14. Madhu *et al.* (2018) investigated the effect of sowing time (November 15, November 30, December 15 and December 30) on four varieties of wheat (BARI Gom-25, BARI Gom-26, BARI Gom-27 and Shatabdi) and obtained significantly higher number of grains per spike from BARI Gom-25 when sown on November 15. Their findings also showed that number of grains per spike decreased significantly with successive delay in sowing. No further report is available on this aspect following sowing time.

2.2.2.6 1000-grain weight

Research of different investigators revealed that sowing time had marked effect on 1000-grain weight of wheat. Abdullah *et al*. (2007) evaluated the effect of four planting time (October 25, November 10, November 25, January 10) on wheat and recorded maximum value in 1000-grain weight from October 25 sown wheat but declined progressively with delayed sowing. Hussain *et al*. (2008) recorded significantly maximum 1000-grain weight from October 25 sown wheat but after that period weight of 1000-grain reduced significantly. They obtained lowest value from wheat sown on December 25. Report of Baloch *et al*. (2010) revealed that wheat sown on October 25 produced the highest 1000-grain weight, but decreased subsequently with successive sowing dates *viz.* November 10, November 25, December 10 and December 25. Jahan and Adam (2015) recorded maximum 1000-grain weight from November 14 sown BARI Gom-25 although there was a gradual decreasing trend with delayed sowing. Madhu *et al.* (2018) recorded significantly highest 1000-grain weight from November 15 sown wheat followed by November 30, December 15 and December 30 respectively.

2.2.2.7 Yield per plant and per hectare

Ansary *et al.* (1989) obtained lower yield with delay sown wheat. Decrease in grain yield of wheat due to delay sowing from November 20 onward was also reported by Singh and Uttam (1999). Shah and Akmal (2002) reported that different varieties responded differently on different sowing dates. Regardless of varieties or cultivars, better yields were obtained when wheat was sown after November 15 and before November 30 (Akhtar *et al.* 2006). Abdullah *et al*. (2007) showed that out of four planting time (October 25, November 10, November 25, January 10), October 25 sown wheat resulted maximum yield but declined progressively with delayed sowing. Shahzad *et al*. (2007) also showed that yield per plant reduced in delayed sown wheat. Hussain *et al*. (2008) found consistent decrease in grain yield with delay in sowing from October 25 to December 25. Ali *et al*. (2010) conducted research during 2003-06 to study the effect of seven sowing time *viz.* November 01, November 10, November 20, November 30, December 10, December 20 and December 30 on three varieties of wheat and recorded significantly higher grain yield from AS-2002 variety when sown on November 10 followed by November 20. Their findings showed that each successive delay in sowing beyond November 20 progressively decreased the grain yield in all varieties and the highest decrease in December 30 sowing was 27.24% compared with November 10.

Findings of Baloch *et al*. (2010) revealed that wheat sown on October 25 produced the highest grain yield although statistically identical to November 10 but significantly different than November 25 and December 25 sown wheat. Their findings also revealed that yield per plant decreased subsequently with successive sowing dates. Hussain *et al*. (2008) carried out an experiment on the effect of sowing time (October 25, November 25 and December 25) on a wheat cultivar ‘Inqulab-91’ where, they obtained significantly higher grain yield from October 25 sown wheat followed by November 25. Jahan and Adam (2015) obtained statistically similar yield from both November 14 and 24 sown BARI Gom-25 but significantly decreased yield beyond the time of November 24. By evaluating the effect of four sowing date (November 15, November 30, December 15 and December 30) on four varieties of wheat, Madhu *et al.* (2018) found significant decreases in wheat yield beyond the time of November 15.

2.2.2.8 Harvest index

Reports regarding the responses of sowing time on wheat are meagre. Hussain *et al*. (2008) recorded significantly higher harvest index in October 25 sown wheat than sown on November 25 and December 25. Jahan and Adam (2015) reported that seed sown on November 14 produced significantly maximum harvest index in BARI Gom-25 but beyond this time harvest index decreased significantly.

2.3 Nitrogen fertilizer

Nitrogen (N) is an essential nutrient required by plants in comparatively larger amounts than the other nutrients. The amount of N fertilizer applied to plants must be carefully managed to ensure that N will be available throughout the growing season, and vegetative and reproductive development will not be restricted (Vidal *et al.* 1999). Our soil is more or less deficient in nitrogen. Almost all soils give positive response to N-fertilizer application. Availability of N has impacts throughout crop development, affecting seedling establishment, tillering, canopy development as well as grain filling, all of which have the potential to influence final yield and together determine the N requirements of the crop. Application of N-fertilizer had significant effect on various economically important crops including wheat (Ottman *et al.* 2000, Alam *et al.* 2005, Hussain *et al.* 2006, Chaturvedi 2006, Sadat *et al.* 2008, Bojović and Marković 2009, Ryan *et al.* 2009, Ali *et al.* 2011, Gul *et al.* 2011, Rahman *et al.* 2011, Alam 2012, Gharekand *et al.* 2012a, Krobel *et al.* 2012, Baukef *et al.* 2013, Dandan and Shi 2013, Gheith *et al.* 2013, Shahzad *et al.* 2013, Aghdam and Samadiyan 2014). However, a large number of studies have recognized the negative impact on yield with increasing fertilizer doses after a certain limit (Huq 1983).

2.4 Naphthalene acetic acid (NAA)

Research findings of different investigations revealed stimulatory effect of NAA (alone or in combination with other substances) on growth, yield and biochemical parameters in a number of crop plants including wheat all over the world (Crane 1964, Chaudhuri *et al*. 1980, Arora *et al*. 1982, Orsi and Tallarico 1983, Sing and Gill 1985, Harshan and Gill 1985, Grewal and Gill 1986, Patel 1992, Saxena 1994, Uddin *et al*.

1994, Jain *et al*. 1995, Kalita *et al*. 1995, Shinde and Jhadav 1995, Klasa *et al*. 1996, Lakshmamma and Rao 1996, Kalarani and Jeyakumar 1998, Sivakumar *et al*. 2001, Naiduv *et al*. 2003, Wang *et al*. 2004, Muthukumar *et al*. 2005, Iqbal *et al*. 2009, Kassem *et al*. 2010, Akram *et al*. 2011, Bakhsh *et al*. 2011, Mona *et al*. 2013).

In Bangladesh, research has also been conducted with NAA on various economically important crops by different investigators (Jahan and Fattah 1991, Jahan *et al*. 1992, Rahman and Nath 1992, Karim *et al*. 2006, Karim and Fattah 2007, Ullah *et al*. 2007, Akter 2010, Adam and Jahan 2011, Adam *et al*. 2012, Jahan and Adam 2013, Jahan and Adam 2014, Akter 2016, Islam and Jahan 2016a and b). From agricultural point of view NAA is a productive chemical when used in proper concentration at proper ontogenic stage. However, the response due to application of NAA depends not only on the concentrations but also on the method of application, plant species, age, weather condition, soil condition etc. Thus, the results obtained elsewhere in the world may not hold good in this country.

2.5 Effects of NAA and N-fertilizer on physiological parameters

A number of research reports on the effects of NAA alone and in combination with N-fertilizer on different plants have been critically reviewed and presented in the following pages character wise and also as far as possible crop wise and not chronologically.

2.5.1 Plant height

Plant height is a varietal character of any crop plant, but may be influenced by management practices and application of growth regulators. Application of NAA has been found to increase and decrease plant height of various crops including wheat. Alam *et al.* (2002) applied NAA (10, 20 and 30 ppm) on three varieties of wheat *viz*. Sarsabz, Soghat and S-232 and obtained increased plant height of soghat variety where decreased in other two varieties. Jahan and Adam (2013) carried out an experiment on the effects of NAA (25, 50, 75 and 100 mg/L) on BARI Gom-26 where they obtained tallest plant from 75 mg/L starting from 35 days after spray up to harvest. But at the early stage of growth (7 and 14 days after spray) plant height also increased due to both

25 and 50 NAA. Reports relating to the effect of NAA on other cereal crops are also available. Akter (2010) found significantly increased plant height at 15, 30 and 45 days after spray following 100 and 200 ppm of NAA in maize. At 60 days after spray, plant height increased significantly due to 100 ppm of NAA, whereas, the decrease due to 200 ppm of NAA was also significant. Bakhsh *et al.* (2011) found that the application of 90 ml per ha NAA at the stage of panicle initiation stage resulted tallest plant in rice. Jahan and Adam (2011) reported both increase and decrease in plant height of two varieties of rice (BRRI Dhan-29 and BRRI Dhan-50) following the application of NAA treatments (100 and 200 ppm).

Investigations on the response of NAA on various crops are also available around the world. Chhonkar and Sing (1959) studied the effect of three different concentrations (50, 100 and 150 ppm) of NAA on tomato and found that the higher concentrations of NAA reduced plant height while the lower concentrations (50 and 100 ppm) increased height. Sing *et al.* (1972) found both increases and decreases in height of the main stem of pea with 10 ppm and 100 ppm of NAA. Maurya and Lal (1975) observed that plant height was improved significantly by lower concentrations of NAA at different stages of growth, and reported that NAA at lower concentration was proved to be most effective in improving almost all growth characteristics of faba bean. The effect of NAA in increasing the plant height was also reported by Yadava and Sreenath (1975) in cowpea. Treating *Phaseolus vulgaris* L. with 100 ppm of NAA Valio and Schwabe (1978) found effective inhibition of stem elongation. Reddy and Rao (1981) reported increase in plant height when barley hybrid treated with 100 ppm of NAA at the 6 or 12 leaf stage or at both stages. Spraying of groundnut with 40 ppm NAA solution, Kelaiya *et al.* (1991) found increase in plant height. Setia *et al.* (1992) noticed that foliar application of NAA (50 and 100 ppm) to lentil plants reduced stem height. Rao (1993) sprayed turmeric plant with NAA at 5, 10, 15 or 20 ppm at 50 to 60 days after planting and found highest plant height with 20 ppm. Uddin *et al.* (1994) by spraying 250-500 ppm NAA on the foliage of lablab bean at 72 days after spray reported the highest internodes length by 500 ppm of NAA. Klasa *et al.* (1996) applied NAA at flowering of faba bean and found decreased plant height at the final harvest. Lakshmamma and Rao (1996) found that in black gram, spraying with 5-20 ppm of NAA at flowering stage progressively increased plant height.

Shoot length of soybean increased by soaking seeds in NAA solution having concentrations from 25-50 ppm but decreased with 150 ppm (Maske *et al*. 1997). Deotale *et al*. (1998) studied the effect of GA_3 and NAA on growth parameter of soybean and obtained highest values for plant height due to 100 mg/L NAA. Applying six different concentrations of NAA (10, 30, 50, 70, 90 and 110 ppm) in cowpea, Ullah *et al*. (2007) found that plant height increased up to 50 ppm of NAA and decreased over 70 ppm.

Reports regarding the effect of NAA in combination with various doses of N-fertilizer on cereal crops including wheat are scanty. Islam and Jahan (2016a) reported that height of BARI Gom-26 increased due to both 25 and 50 ppm of NAA in combination with 50% of N-fertilizer at all the ages except at 15 days after spray and the increases in both the cases were more than those of full dose of N-fertilizer application alone. Their findings also revealed that foliar application of 50 ppm NAA in combination with 50% N-fertilizer resulted tallest plant. In BARI Sweet corn-1, Akter (2016) reported that plant height of wheat increased due to combined application of NAA and N-fertilizer treatments (25 and 50 ppm in combination with recommended dose and 50, 100 and 150% higher dose of N-fertilizer) where the tallest plant was recorded from 50 ppm NAA in combination with 150% higher rate.

2.5.2 Number of tillers per plant

The yield of cereals has been shown to be dependent mainly on the number of effective tillers per plant. Alam *et al.* (2002) observed that number of tillers per plant in Sarsabz variety of wheat increased following 10, 20 and 30 ppm NAA application but decreased in other two varieties *viz.* Soghat and S-232. Jahan and Adam (2013) reported that number of tillers per plant in wheat increased due to 25 and 50 ppm NAA but decreased due to 75 and 100 ppm. Reports regarding the application of NAA on other cereal crops are also available. Chaudhuri *et al.* (1980) showed beneficial effect of NAA spray on tillering in rice. Adam and Jahan (2011) recorded that number of tillers per plant increased due to 100 ppm NAA in BRRI Dhan-29 and decreased due to both 100 and 200 ppm in BRRI Dhan-50. By spraying growth regulator mixture containing IAA + NAA (0+0, 50+25, 100+50 and 150+75 ppm), Mona *et al.* (2013)

had found significant promotive effect on the number of tiller of barley where the highest value was obtained from 150 ppm IAA + 75 ppm NAA treatment.

However, very limited research has been done on the effects of NAA in combination with N-fertilizer on wheat. Islam and Jahan (2016a) reported that foliar application of NAA in combination with various doses of N-fertilizer resulted higher number of tillers per plant of BARI Gom-26 throughout the growth period with significant variations at 15, 30 and 45 days after spray. They also reported that after 15 days after spray, the maximum number of tillers per plant was found from 25 ppm NAA in combination with 50% N-fertilizer.

2.5.3 Number of leaves per plant

Leaf is directly involves to plant growth by its photosynthetic activities. The number of leaves of a plant may differ due to genetical and environmental factors, and also due to fertilization, irrigation and cultural practices. Naphthalene acetic acid at appropriate quantity have significant influence on leaf numbers. By spraying with 100 ppm NAA, Harsharn and Gill (1985) reported about significant increase on the number of leaves per plant in late sown wheat and barley. Jahan and Adam (2013) obtained higher number of leaves in BARI Gom-26 following 25 and 50 ppm NAA application whereas, number of leaves decreased due to 75 and 100 ppm NAA. Reports regarding the response of NAA on other cereal crops are available. Applying NAA at mid tillering and panicle initiation stages on two cultivars of rice, Chaudhuri *et al*. (1980) found increased number of leaves per plant. Bnu and Huang (1980) also reported that 50 ppm of NAA with sodium nitro phenol increased number of leaves in rice. Akter (2010) reported both increase and decrease in number of leaves of maize due to both 100 and 200 ppm NAA at different ages. Jahan and Adam (2011) also found increased number of leaves in a rice variety, BRRI Dhan-29 following 100 ppm of NAA.

Report on the increase in number of leaves following NAA in combination with N-fertilizer have also been reported in different cereal plant. Islam and Jahan (2016a) reported that number of leaves of BARI Gom-26 was recorded higher following combined application of NAA and N-fertilizer. They obtained highest number of leaves from 25 ppm NAA in combination with 50% N fertilizer with significant variations at

15, 30 and 45 Days after spray. On the other hand, application of NAA (25 and 50 ppm) and N-fertilizer levels (Recommended, 50, 100 and 150% higher rate) increased the number of leaves of BARI Sweet corn-1 up to the age of 60 days but after the age of 60 days it was decreased following all treatments (Akter 2016).

2.5.4 Total dry matter per plant

Total dry matter (TDM) of any crop is the accumulated product of photosynthesis; consequently it is affected by the crop’s total photosynthetic area (Watson 1966). Dry matter production after flowering is also positively correlated with grain yield (Yoshida and Ahn 1968). Alam *et al*. (2002) conducted an experiment using 0, 10, 20 and 30 ppm NAA on the growth of three wheat cultivars *viz*. Sarsabz, Soghat and S-232 and found better results in straw yield with 20 ppm. By applying 100 and 200 ppm NAA, Akter (2010) recorded significant increase in dry weight of maize at harvest. Findings of Adam (2010) also revealed that dry weight of shoot increased due to both 100 and 200 ppm NAA treatments throughout the growth ages of BRRI Dhan-29 except at 15 days after spray whereas, the same concentration had retarding effect after 30 days after spray in case of BRRI Dhan-50.

Enhanced increases in total biomass of different crops due to NAA application are available. Karim and Fattah (2007) reported that foliar spray of NAA has greater influence on total dry matter in chickpea. They obtained maximum dry matter per plant from 20 ppm NAA where dry matter tended to decrease with further increase in the concentration. Ullah *et al*. (2007) reported that in cowpea the dry matter per plant increased with increasing concentrations of NAA but up to 50 ppm. The stimulatory effect of NAA on total biomass have also been reported in black gram (Saxena 1994, Lakshmamma and Rao 1996), fiber hemp (Geel *et al*. 1994), cotton (Pothiraj *et al.* 1995), potato (Ahmed and Tahir 1995, Puste and Kundo 1995) and green gram (Patel and Saxena 1994, Kalita *et al*. 1995).

Application of NAA in combination with N-fertilizer has also stimulatory effect on cereal plants. Islam and Jahan (2016a) obtained maximum dry mater from 25 ppm NAA in combination with 75% N-fertilizer at 45, 60 days after spray and at harvest of BARI Gom-26. They also obtained higher dry matter from 50 ppm NAA in combination with 50% N-fertilizer over the full dose of N-fertilizer at all the growth stages. In addition, Akter (2016) conducted an experiment on BARI Sweet Corn-1 for the evaluation of the effect of NAA (25 and 50 ppm) at varying N-levels (recommended dose, 50, 100 and 150% higher dose) and obtained both increase and decrease in dry weight of leaves, stem and root depending on the growth stages.

2.6 Effects of NAA and N-fertilizer on yield attributes and yield

2.6.1 Number of effective tillers (spikes) per plant

Reports are available regarding the effect of NAA on the number of effective tillers per plant of various cereal crops including wheat. Orsi and Tallarico (1983) and Sing and Gill (1985) reported that foliar spray of NAA favourably influenced the source and sink mechanism, which reflected to have a significant effect on the number of ear bearing tiller in late sown wheat and barley. Akter (2010) observed non-significant increases in number of cob per plant due to both 100 and 200 ppm of NAA treatment in maize and the maximum increase was due to 100 ppm. Adam and Jahan (2011) found that number of panicle per plant increased following 100 ppm NAA and decreased due to 200 ppm in BRRI Dhan-29 whereas application of these both treatments had retarding effect in BRRI Dhan-50. Bakhsh *et al.* (2011) conducted a study during 2004 and 2005 to find out the growth behavior of transplanted coarse rice (IR-6) as influenced by NAA treatments (0, 60, 90 and 120 ml per ha) and recorded highest number of panicles from 90 ml per ha followed by 60 ml per ha during both the year of study. Jahan and Adam (2013) obtained significantly higher number of effective tillers per plant from 50 ppm NAA application in BARI Gom-26. They also reported that 25, 75 and 100 ppm NAA had retarding effect on this trait. Mona *et al.* (2013) reported that in barley number of spikes per plant was significantly elevated after spraying with the growth regulator mixture containing IAA+ NAA (50+25, 100+50 and 150+75 ppm) in comparison to control. They obtained highest number of spikes from 150 IAA+75 NAA treatment.

Research reports regarding this aspect are also available on crops other than cereals. Sing *et al.* (1972) by soaking seeds of pea in 10 ppm of NAA solution found increased number of pods per plant, which however, was decreased when soaked in 100 ppm solution. Bangal *et al.* (1982) noticed an increase in number of pods per plant over control by 10.2 to 24.4% following double spray of 25 and 50 ppm NAA at an internal of 5 days at flowering. Deshai and Deore (1985) applied Na salt of NAA on cowpea at concentrations of 10, 20, 30, 40 and 55 ppm and found maximum number of pods per plant with 10 ppm. Katageri and Sheelvantar (1985) obtained increase in number of pods per plant over control due to 10 ppm NAA treatment at the onset of flowering in chickpea. Foliar application of NAA, at anthesis and 10 days later, increased the number of pods of green gram plant compared with control (Sharma and Sharma 1989). Kelaiya *et al.* (1991) by spraying groundnut foliages with 40 ppm NAA solution reported increased number of pods per plant. Kar *et al.* (1993) reported that the application of IAA, NAA (both at 15, 25 or 50 ppm) as a seed pre soak+spray gave the best fruit retention and yield in tomato cv. Pusa Early Dwarf. Uddin *et al.* (1994) obtained highest number of pods per plant by spraying 500 ppm NAA on the foliage of lablab bean at 72 days after spray. Kalita *et al.* (1995) applied 50 and 100 ppm of NAA on green gram and obtained higher number of pods per plant with 100 ppm NAA in combination with 3.00% P_2O_5. Number of pods per plant of faba bean increased due to NAA application (Nowak *et al.* 1997). Number of pods of pigeon pea was increased by the application of 20 ppm NAA when applied at 10 days interval at reproductive stage from 80-120 days after spray (Rao and Narayanan 1998). Ullah *et al.* (2007) reported increased number of pods per plant up to 50 ppm NAA but with further increase in concentration, number of pods per cowpea plant decreased.

Literature relating to the effects of NAA in combination with N-fertilizers is very limited on wheat. Application of NAA (25 and 50 ppm) in combination with various N-levels (50, 75 and 100% of recommended dose) resulted significantly higher number of effective tillers per plant in BARI Gom-26 where, the maximum value was recorded from 25 ppm NAA in combination with 75% N-fertilizer (Islam and Jahan 2016a). Results of Akter (2016) revealed that foliar application of NAA (25 and 50 ppm) at various N-levels (recommended dose, 50,100 and 150% higher dose) produced higher number of productive cobs in maize than control but with few exceptions.

2.6.2 Number of non-effective tillers per plant

A very few reports have been found regarding the effect of NAA on number of non-effective tillers of wheat crop. Jahan and Adam (2013) found significantly lower number of non-effective tillers in BARI Gom-26 from 50 ppm NAA application in comparison to control. They also found that 25, 75 and 100 ppm NAA had almost statistically similar response to control. Islam and Jahan (2016a) obtained lowest number of non-effective tillers per plant from 25 ppm NAA alone although, higher number of non-effective tillers per plant was recorded from both 25 and 50 ppm NAA in combination with 50% of N-fertilizer. Akter (2016) found both positive and negative response on the number of non-productive cobs of maize plant following NAA treatments (25 and 50 ppm) in combination with various N-levels *viz.* recommended dose, 50, 100 and 150% higher than recommended dose where she recorded minimum number of non-effective tillers from plants treated with 50 NAA with recommended N-level.

2.6.3 Length of spike

Length of spike is an important yield contributing parameter and closely associated with other yield components *viz.* number of grains and grain weight. Alam *et al.* (2002) showed that length of earhead was unaffected following 10, 20 and 30 ppm NAA application in all three varieties *viz.* Sarsabz, Soghat and S-232. Jahan and Adam (2013) obtained maximum length of spike in BARI Gom-26 with 50 ppm NAA although statistically not different from control. They also found non-significantly higher length of spike following rest of the treatments (25, 75 and 100 ppm). Reports regarding the response of NAA in this aspect are also available on other cereals crops. Akter (2010) recorded increased cob length due to both 100 and 200 ppm of NAA application in maize. Adam and Jahan (2011) obtained higher length of panicle following 100 and 200 ppm NAA treatments in BRRI Dhan-29, although the trend was reversed in BRRI dhan-50.

Literature regarding the combined application of NAA and N-fertilizers are scanty on wheat. Akter (2016) found that length of maize cob increased following both 25 and 50 ppm NAA in combination with various rates of N-fertilizer (recommended dose, 50, 100 and 150% higher dose) with an exception of 50 ppm in combination with 50% higher rate of N-fertilizer. Islam and Jahan (2016a) recorded increased length of spike of BARI Gom-26 due to all application of NAA and N-fertilizer levels where, the maximum value was obtained from 50 ppm NAA in combination with 75% N-fertilizer.

2.6.4 Dry weight of spike

Inadequate research has been done on the effect of NAA alone and in combination with N-fertilizer on wheat crops. Alam *et al.* (2002) evaluated the responses of NAA (0, 10, 20 and 30 ppm) on three varieties of wheat *viz.* Sarsabz, Soghat and S-232 and reported that dry weight per earhead decreased due to application of NAA treatments in all varieties except due to 20 and 30 ppm in case of S-232 variety. Research findings relating to the effect of NAA on other cereals crops are available. Report of Adam (2010) revealed that dry weight of panicle increased following 100 and 200 ppm NAA treatments in BRRI Dhan-29, but, decreased in BRRI Dhan-50. Akter (2010) reported about significant increase in dry weight of cob due to both 100 and 200 ppm NAA where, the increase due to 100 ppm NAA was 34.61% over the control.

Islam (2015) applied 25 and 50 ppm NAA in combination with varying N-fertilizers (50, 75 and 100% of recommended dose) on BARI Gom-26 and recorded better result from the interaction of 25 ppm NAA with 75% of the N-fertilizer than that obtained from NAA or N alone. In Maize, Akter (2016) showed that dry weight of tassel increased due to the application of 25 and 50 ppm NAA in combination with various N-levels (recommended dose, 50, 100 and 150% higher dose) in most cases where, the maximum value was obtained from 50 ppm NAA in combination with 100 % higher rate of N fertilizer.

2.6.5 Number of grains per spike and per plant

Number of grains per spike is an important yield component of wheat. Literatures regarding the influence of NAA alone and in combination with various doses of N-fertilizer are meagre on wheat. By applying different NAA treatments

(0, 60, 90 and 120 ml per ha) during both 2004 and 2005 study year in transplanted coarse rice (IR-6), Bakhsh *et al.* (2011) recorded highest number of spikelets per panicle from 90 ml per ha followed by 60 ml per ha. Adam and Jahan (2011) recorded higher number of grains per panicle in BRRI Dhan-29 following 100 and 200 ppm NAA. However, the number of grains per panicle decreased due to both the treatments in other variety (BRRI Dhan-50). Islam and Jahan (2016a) reported that application of NAA in combination with different N levels had significant response on the number of grains per spike of BARI Gom-26. They obtained maximum number of grains per spike from 25 ppm NAA in combination with 75% of the N-fertilizer which was also higher than those of full recommended dose of N fertilizer. Findings of Akter (2016) revealed that number of karnels of BARI Sweet corn-1 increased due to all combined application of NAA (25 and 50) and N-fertilizers (25 and 50 ppm in combination with recommended dose, 50, 100 and 150% higher dose).

Limited research has been done on the effect of NAA alone and in combination with varying N-levels on the number of grains of any wheat variety. Research of Islam and Jahan (2016a) revealed that number of grains of BARI Gom-26 was significantly influenced by interaction of NAA (25 and 50 ppm) and N levels (50, 75 and 100% of recommended dose). They obtained the maximum number of grains per plant from 25 ppm NAA in combination with 75% of the N-fertilizer dose.

2.6.6 1000-grain weight

Weight of grain or seed is a vital yield attributing character. Weight of grains depends on size of grain which varies with cultivars. Reports regarding increase and decrease in 1000-grain weight of different plants due to NAA application are available. Chen *et al.* (1984) found non-significant increase in 1000-seed weight of wheat due to 50 ppm NAA treatment. Spraying with 100 ppm of NAA in late sown wheat and barley at tillering and heading stage, Harsharn and Gill (1985) obtained significantly higher 1000-seed weight than the untreated plants. Findings of Jahan and Adam (2013) showed that foliar application of NAA (25, 50, 75 and 100 ppm) non-significantly increased 1000-seed weight of BARI Gom-26 where the maximum was recorded from 50 ppm NAA application. Reports regarding this aspect are also available on other cereal crops. Significantly higher thousand seed weight of maize was obtained from

100 and 200 ppm NAA treatments where, the maximum was due to 100 ppm (Akter 2010). By spraying different NAA treatments (0, 60, 90 and 120 ml per ha) during 2004 and 2005 in transplanted coarse rice (IR-6), Bakhsh *et al.* (2011) found significantly maximum 1000-grain weight from 90 ml ha^{-1} NAA application at panicle initiation stage followed by 60 ml per ha. Adam and Jahan (2011) reported that 1000-grain weight of two varieties of rice, BRRI Dhan-29 and BRRI Dhan-50 decreased due to both 100 and 200 ppm NAA application.

Research results are also available regarding the effect of NAA on many other crops. Seeds soaking with 10 ppm NAA solution increased thousand seed weight of pea (Sing *et al.* 1972). In cowpea, NAA application had positive response on 1000-seed weight (Kaul *et al.* 1976). Planofix (NAA) increased 100-seed weight in groundnut at 40 and 50 days after sowing (Singh and Sharma 1982). Bangal *et al.* (1983) showed that foliar application of 25-50 ppm NAA to chickpea thrice at 5-days interval, beginning at flowering stage increased seed and pod weight. Suty (1984) reported that Rhodofix (NAA) at 3.4 g per ha increased 100 seed weight. Ravikumar and Kulkarni (1988) showed that 100-seed weight was increased with the foliar application of 20 mg/L NAA. Sharma and Sharma (1989) found higher seed weight of 1000-seed compared with untreated plant due to foliar application of NAA in green gram. Application of 40 ppm NAA resulted bigger seed in ground nut (Kelaiya *et al.* 1991). Upadhayay *et al.* (1993) found higher value of 1000-seed weight of green gram due to 50 and 100 ppm of NAA. In cowpea, Ullah *et al.* (2007) reported increased 1000-seed weight due to 10 and 30 ppm NAA and decreased due to 90 and 110 ppm NAA.

Islam and Jahan (2016a) reported that 100-seed weight of BARI Gom-26 was both positively and negatively influenced by different treatments (25 and 50 ppm in combination with 50, 75 and 100% N-rate). They found maximum value from 25 ppm NAA in combination with 75% N-fertilizer followed by 50 ppm NAA in combination with 50% N-fertilizer. Akter (2016) applied NAA (25 and 50) treatments at varying N-levels on maize and observed significant response on 1000-grain weight. She also observed that the maximum 1000-grain weight was obtained from 50 NAA at 50% higher rate of N-fertilizer.

2.6.7 Yield per plant and per hectare

Alam *et al*. (2002) observed the responses of 10, 20 and 30 ppm NAA on three varieties of wheat *viz.* Sarsabz, Soghat and S-232 and obtained higher yield from all concentrations of NAA in both Sarsabz and S-232 varieties except due to 10 ppm in case of S-232. They also showed that 20 ppm NAA had better response in enhancing grain yield of Sarsabz and S-232 varieties. However, yield of Soghat variety decreased following all NAA treatments. Jahan and Adam (2013) applied NAA as foliar spray on BARI Gom-26 and obtained 12.24 % higher yield over the control due to 50 ppm NAA application. They also reported that application of 25, 75 and 100 ppm NAA treatments had retarding effect on yield of BARI Gom-26. A number of investigators also reported about the effect of NAA on grain yield of other cereal crops. Findings of Misra and Sahu (1957) revealed that application of 100, 250 and 500 ppm of NAA influenced the number of spikelet and grain without affecting grain yield. Chaudhuri *et al.* (1980) observed beneficial effect of NAA spray in paddy yield. Sahu and Murty (1981) showed that foliar spray of 50 ppm of NAA applied at the tillering and booting stage and 7 days after flowering increased grain yields of rice. Application of 50 ppm of NAA at the early stage increased grain yield in sorghum (Thakre 1985). Tulsa-Ram *et al.* (1997) obtained maximum net return and benefit-cost ratio in sorghum following NAA application. Muthukumar *et al.* (2005) reported that grain yield of maize increased by 32.34% and 14.94% due to application of 100 and 200 ppm of NAA respectively. Adam and Jahan (2011) reported that yield per plant of BRRI Dhan-29 increased due to 100 ppm only whereas, yield of BRRI Dhan-50 decreased due to both 100 and 200 ppm treatments.

Increased grain yield due to NAA application has also been reported by different investigators in other crops. Application of 50 ppm NAA along with TIBA, produced highest yield in sunflower (Vasudevan *et al.* 1967). Kaul *et al.* (1976) observed increased seed yield of cowpea due to NAA application. Khan and Chowdhury (1976) obtained increase in chickpea yield following 10 ppm of NAA treatment. Bangal *et al.* (1982) reported up to 36% more seed yield in chickpea with the use of 25 ppm or 55 ppm NAA as foliar application during flowering stage of the crop. By applying 10, 20, 30, 40 and 50 ppm Na salt of NAA on cowpea Deshai and Deore

(1985) recorded highest yield with 10 ppm treatment. Katageri and Sheelvantar (1985) obtained 10% more seed yield by using 10 ppm NAA at flower initiation stage of chickpea. Bai *et al*. (1987) applied eight foliar sprays of 25 ppm NAA at 7 days intervals to *Vigna radiata* and reported a significant increase in seed yield and yield components. Brenner (1987) demonstrated significant improvement in seed yield of lentil by spraying different concentrations of NAA. Singh (1989) obtained higher seed yield in chickpea with 20 ppm NAA. By soaking seeds in 10, 20, 40 and 60 ppm NAA solutions Borkar *et al.* (1991) reported that yield of cowpea decreased with increasing NAA concentrations over 40 ppm.

Kelaiya *et al.* (1991) reported increased yield of ground nut with 40 ppm NAA spray. Foliar spray of 5 ppm NAA resulted highest yield of cowpea cv. VCM-8 (Shinde *et al.* 1991). Setia *et al.* (1992) also obtained increased seed yield of lentil due to NAA application. Upadhyay *et al.* (1993) noticed increase in yield due to 20 ppm NAA at flowering stage of chickpea crop. Geel *et al.* (1994) reported that application of 10 ppm NAA had little effect on the increase of the yield of fiber hemp. Ahmed and Tahir (1995) obtained increased yield of potato due to spraying of 100 ppm of NAA. Yield of dolichos bean was slightly increased by the application of NAA (Deshai *et al.* 1995). By spraying 15, 30 and 45 ppm of NAA on the foliage of cowpea (cv. Y. L. 175) grown with 40 kg N-per ha, Jain *et al.* (1995) found maximum yield with 45 ppm treatment. Pothiraj *et al*. (1995) observed an increased seed yield of cotton. Increase in yield of potato following NAA application was also reported by Puste and Kundo (1995). Shinde and Jhadav (1995) sprayed 5, 10 and 20 ppm NAA at pre flowering and pod filling stages of cowpea (cv. Konkan Sadabahar) and observed that yield was increased over control by 48% with 5 ppm. By spraying 5-20 ppm of NAA at flowering stage Lakshmamma and Rao (1996) found that the yield of black gram progressively increased. Singh and Sharma (1996) reported an increased grain yield of cowpea by spraying 10-40 ppm NAA on the foliage at 10, 30 and 45 days after sowing. Tripathy *et al.* (1996) applied 10, 20 and 40 ppm NAA on summer sesame and reported that the grain yield was increased up to 16.7% due to 20 ppm NAA. Shukla *et al.* (1997) concluded that a double spray of growth regulators gave 17.7% higher seed yield over the control. Deotale *et al.* (1998) studied the effect of GA_3 and NAA on growth parameter of soybean and obtained highest seed yield with 100 ppm NAA. Grain yield of pigeon pea increased due to application of 20 ppm NAA at 10 days interval during 80-120 Days after spray (Rao and Narayanaa 1998). Ullah *et al.* (2007) reported increased yield in cowpea with the increasing concentrations of NAA from 10 ppm to 50 ppm and decreased over 50 ppm.

Reports of Iqbal *et al.* (2009) revealed that fruit yield of guava plant was significantly increased by NAA application and maximum yield was recorded from 45 ppm treatment. Kassem *et al.* (2010) found increase in yield of *Costata persimmon* tree with 25 ppm of NAA.

But, reports connecting to the effect of NAA in combination with various N-levels are inadequate on wheat. Findings of Islam and Jahan (2016a) revealed that yields per plant and per hectare of BARI Gom-26 were significantly affected by different concentrations of NAA treatments (25 and 50 ppm) and also in combination with various N-fertilizer levels (50, 75 and 100% of recommended dose). The maximum yield was recorded from the plants treated with 25 ppm NAA in combination with 75% N-fertilizer application. However, Akter (2016) reported that yield of BARI Sweet Corn-1 increased following both 25 and 50 ppm NAA at various N levels (recommended, 50, 100 and 150% higher dose) where, 50 NAA at recommended rate of N fertilizer produced maximum yield with significant variations.

2.6.8 Harvest index

The relationship of the economic yield to the biological yield is expressed as the "co-efficient of effectiveness" or harvest index (HI). The HI is positively correlated with yield and thus is useful measure of yield efficiency (Singh and Storskopf 1971). Literatures are inadequate regarding the effect of NAA alone or in combination with N-fertilizers on harvest index of wheat. Jahan and Adam (2013) reported that foliar application of NAA (25, 50, 75 and 100 ppm) had both positive and negative response on harvest index of BARI Gom-26 but with non-significant responses. They obtained higher values from 50 and 100 ppm treatments. In case of combined treatments (25 and 50 ppm in combination with 50, 75 and 100% N-levels), Islam and Jahan (2016a) recorded maximum harvest index from 25 ppm NAA treatment in combination with 75% N-fertilizer application followed by 50 ppm NAA in combination with 50%

N-fertilizer in BARI Gom-26. However, Akter (2016) obtained that on maize 50 ppm NAA at recommended rate of N fertilizer produced the maximum value.

2.7. Effects of NAA and N-fertilizer on biochemical parameters

2.7.1 Pigment contents of leaves

Chlorophyll is related to yield in plants as utilization of solar energy mainly depends on the relative amount of efficiency of the photosynthetic pigments. It has been observed that in many cases, NAA stimulate photosynthesis owing to increased assimilative power and thereby resulting better growth, development and higher yield. A large number of reports are available on the effect of NAA on pigment content of leaves of various cereal crops including wheat. Chaudhuri *et al.* (1980) found the beneficial effect of NAA spray on the chlorophyll content in rice. Singh and Gill (1985) and Orsi and Tallarico (1983) reported on wheat and barley that chlorophyll content of leaves improved with NAA spray and increase due to 100 ppm of NAA is more significant than 500 ppm. Akter (2010) found increased chlorophyll a (chl. a) content of leaves due to both 100 and 200 ppm of NAA application in maize but, in case of chlorophyll b (chl. b) and carotenoids contents the increases were due to 200 ppm only. Jahan and Adam (2014) reported that pigment contents *viz.* chl. a, chl. b and carotenoids of leaves increased due to 100 and 200 ppm NAA at flowering and grain filling stages of BRRI Dhan-29 whereas, decreases in pigment contents due to both of these treatments were observed at tillering stage. They found significant variations in chl. a and b contents at the flowering stage and carotenoids content at grain filling stage of BRRI Dhan-29. However, in case of BRRI Dhan-50, pigment contents of leaves were positively influenced only at tillering stage but with few exceptions.

Reports regarding the effects of NAA on pigment contents of leaves has also been presented by different investigators on other crops. Jahan *et al.* (1992) reported that in bitter gourd chlorophyll contents of leaves increased following single application of NAA at the flower initiation stage. Upadhyay *et al.* (1993) noticed improved chlorophyll content in chickpea leaves with 20 ppm NAA application. Lakshmamma and Rao (1996) showed that spraying of 5-20 ppm of NAA at flowering stage of black gram progressively increased the chlorophyll content of leaves. By spraying 0.04% solution of NAA at 35th and 75th days after spray, Kalarani and Jeyakumar (1998) observed that at 40, 60 and 80 days after spray, total chlorophyll content of soybean leaves were increased to 2.08, 2.21 and 1.68% from 1.99, 2.14 and 1.34% of untreated leaves respectively.

Very limited research has been done on the effect of NAA in combination with N-fertilizers on wheat. By applying 25 and 50 ppm NAA in combination with varying N-levels (50, 75 and 100%), Islam (2015) estimated pigment contents of leaves at two different stages of BARI Gom-26 and found significant variations at flowering stage and non-significant at grain filling stage. It was observed that application of NAA in combination with various N-levels resulted significantly higher chl. a and chl. b content of leaves than control except 25 ppm NAA in combination with 50% of recommended N-level at flowering stage. Although, in case of carotenoids content all treatments had statistically similar response to control. Results also revealed that at grain filling stage pigments content of leaves increased due to all combined treatments stage except chl. b content due to 75 and 100% N-levels. Akter (2016) showed that application of 25 and 50 ppm NAA in combination with recommended dose, 50, 100 and 150% higher doses of N-fertilizers had negative response on pigment content of leaves at tassel initiation stage of maize. However, both increase and decrease in leaves pigment was noted at grain filling stage.

2.7.2 N, P and K contents and uptake by shoot

Literatures relating to the effects of NAA alone and in combination with N-fertilizer on nitrogen (N), phosphorus (P) and potassium (K) contents of wheat are limited. Purbey and Sen (2007) showed that NPK content of fenugreek were maximum due to 20 ppm NAA which was closely followed by 10 ppm NAA treatment. By applying 100 and 200 ppm NAA on two varieties of rice *viz.* BRRI Dhan-29 and BRRI Dhan-50, Adam (2010) reported that at tillering stage N content in shoot increased due to 100 ppm NAA in BRRI Dhan-29 and due to both the 100 and 200 ppm NAA in BRRI Dhan-50. Whereas, at harvest N content in shoot increased due to both 100 and 200 ppm only in BRRI Dhan-50. Reports of Adam (2010) also showed that P content in shoot of BRRI Dhan-29 was not affected positively at any stage of growth however, in case of BRRI Dhan-50 it was increased following both the treatments at tillering and harvest stages. His findings showed that K content in shoot increased due to both 100 and 200 ppm NAA at flowering stage of BRRI Dhan-29 and at harvest of BRRI Dhan-50. Akter (2010) applied 100 and 200 ppm NAA on maize and recorded higher NPK contents of stem and leaves at 45 and 94 days after spray due to both the treatments.

Findings of Islam (2015) revealed that 25 and 50 ppm NAA in combination with various N-levels (0, 50, 75 and 100% of recommended dose) produced higher N content in shoot than control treatment at both flowering and grain filling stages. Findings also revealed that all combined treatment resulted significantly higher N content at grain filling stage. Results of Islam (2015) also showed that 25 ppm NAA in combination with 50, 75 and 100% N-level produced higher P content in straw at flowering stage where significantly maximum content was obtained from 25 ppm in combination with 100% N-level. Whereas, at grain filling stage, non-significantly higher amount of P content in shoot was recorded from 25 ppm NAA in combination with 100% N-level only. In case of K content, combined application of these treatments resulted non-significantly higher value than control except 25 ppm NAA in combination with 100% N-level at flowering stage. In case of grain filling stage, higher K content was also recorded from combined treatments except due to 25 ppm NAA in combination with 50% N-level treatment.

Research findings regarding the effects of NAA alone and in combination with N-fertilizer on NPK uptake by wheat are scanty. In Fenugreek, Purbey and Sen (2007) recorded highest NPK uptake value from 20 ppm NAA followed by 10 ppm treatment. Islam and Jahan (2016b) conducted an experiment to study the effects of foliar application of NAA (0, 25 and 50 ppm) in combination with varying nitrogen levels (0, 50, 75 and 100% of recommended dose) on BARI Gom-26 and reported that application of combined treatments had significant response on P and K uptake by shoot at flowering stage and NPK uptake at grain filling stages. Findings also revealed that N uptake by shoot at the grain filling stage increased following all the treatments and the highest uptake was recorded from 25 ppm NAA in combination with 75% N-fertilizer. They also found both increase and decrease in P uptake by shoot due to different treatments. Combined application of NAA and N-fertilizer resulted higher K uptake than control at both flowering and grain filling stages.

2.7.3 N, P and K contents and uptake by root

Research report linking to the effect of NAA alone and in combination with different N-levels on NPK content and uptake by root are meagre on cereal crops including wheat. Adam (2010) applied 100 and 200 ppm NAA on two varieties of rice (BRRI Dhan-29 and BRRI Dhan-50). Findings of him revealed that in both varieties N content was influenced positively by both the NAA treatments at harvest stage except due to 100 ppm NAA in BRRI Dhan-29. In case of P content, 100 ppm NAA had stimulatory effect at tillering stage of both the varieties. At flowering stage, N and P content in root decreased due to both treatments in both varieties except P content due to 100 ppm. Report of Adam (2010) showed that 200 ppm NAA had inducing effect on P content of root at harvest stage of both varieties. He also showed that NAA treatments had positive response on K content in root at different stages of both the varieties but with minor exception.

Islam and Jahan (2016b) reported that foliar application of NAA at varying N-levels (0, 25 and 50 ppm in combination with 50, 75 and 100% N) had significant effect on N, P and K uptake by root at flowering and P and K uptake at grain filling stages. Nitrogen uptake by root was recorded higher due to NAA treatments at varying nitrogen levels at both flowering and grain filling stages. Findings of Islam and Jahan (2016b) also revealed that K uptake by root increased following all the treatments whereas, both increase and decrease in P uptake were observed due to different treatments at both the stages. Findings of them also indicated that the maximum percentage uptake was obtained from K followed by N and P respectively in both stages.

2.7.4 N, P and K contents and uptake by grain

Reports regarding the effects of NAA on NPK content of grains are limited on different crops. Purbey and Sen (2007) recorded maximum NPK content and uptake by fenugreek grain from 20 ppm NAA followed by 10 ppm application. Akter (2010) recorded higher NPK contents of grain due to both 100 and 200 ppm of NAA application in maize. By applying 100 and 200 ppm NAA on BRRI Dhan-29 and BRRI Dhan-50, Adam *et al.* (2012) obtained increased NPK content in grain due to 200 ppm NAA treatment except K content of BRRI Dhan-29. They also reported that 100 ppm NAA had mostly retarding effect on NPK concentration in grain of both the varieties. Only one report is available on the effect of NAA in combination with N-fertilizer on NPK content on wheat. Islam and Jahan (2016b) showed that application of 25 and 50 ppm NAA at varying nitrogen levels (50, 75 and 100% of recommended dose) had beneficial effect on NPK content in grain of BARI Gom-26.

2.7.5 Nitrogen use efficiency (NUE) of shoot, root and grain

A single report relating to the effect of NAA alone or in combination with different N-levels on cereal crops is available. Islam and Jahan (2016b) applied 25 and 50 ppm NAA in combination with various N-levels (0, 50, 75 and 100% of recommended dose) on BARI Gom-26 and found significant variations in case of root at flowering stage and shoot at grain filling stage. They obtained highest NUE of shoot and total plant from 50 ppm NAA in combination with 50% N-fertilizer followed by 25 ppm in combination with 75% N-level at flowering stage. The NUE of shoot and total plant at grain filling stage were recorded from 25 ppm NAA in combination with 75% N-fertilizer followed by 25 ppm NAA in combination with 50% N-fertilizer. Their findings revealed that NUE of root at flowering stage were recorded higher from 25 ppm NAA in combination with 75% and 50 ppm NAA in combination with 50 and 75% of recommended N treatments. At grain filling stage, maximum NUE of root was obtained from 25 ppm NAA in combination with 50% N-fertilizer.

2.7.6 Nutritional parameters of grain

2.7.6.1 Carbohydrate content of grain

Report relating to the effect of NAA alone and in combination with N-fertilizer on carbohydrate content of cereal grain is limited. Akter (2010) recorded higher amount of carbohydrate content in maize grain due to both 100 and 200 ppm of NAA application. Jahan and Adam (2014) applied 100 and 200 ppm NAA on two varieties of rice *viz.* BRRI Dhan-29 and BRRI Dhan-50 and obtained higher carbohydrates content in grain due to both the treatments in both varieties where, the maximum increase was due to 100 ppm treatment. Similar research has been done by different investigators on other plants. Deshai and Khanvilkar (1997) reported that carbohydrate content in grains of Bengal gram decreased following the application of 100 ppm NAA treatment. Karim *et al.* (2006) applied NAA (10, 20 and 30 ppm) on chickpea and recorded higher carbohydrate content following the application of 20 ppm. By applying different concentrations of NAA (10, 30, 50, 70, 90 and 110 ppm), Ullah (2006) found both increase and decrease in carbohydrate content of cowpea seeds. Olaiya *et al.* (2010) reported that carbohydrate content in tomato significantly reduced following NAA treatments (60, 100 and 140 mg per L) compared to control. Noor *et al*. (2017) showed that total carbohydrate content of French bean reduced significantly due to NAA treatments (50, 70, 90 and 110 ppm) at 58 days after sowing (DAS) and the maximum decrease was due to the application of 50 ppm. But, report regarding the effect of NAA alone and in combination with N-fertilizer on carbohydrate content of wheat grain is available.

2.7.6.2 Protein content of grain

The excellence of wheat is directly related to protein content. High protein content in wheat is a significant consideration for human nourishment. Although research report regarding the effect of NAA on protein contain of any varieties of wheat is unavailable but are available on other crops. Singh and Jain (1982) obtained higher protein content in chickpea seeds due to the foliar application of 20 ppm of NAA. Jahan *et al.* (1992) reported that the protein contents of fruits of bitter gourd were increased due to application of 400 ppm NAA. Dhingra *et al.* (1995) also recorded increased protein content in chickpea seeds following NAA application. Lakshmamma and Rao (1996) observed that the protein content of black gram seed was increased progressively following the application of NAA at different concentrations ranging from 0-20 ppm. By applying three concentrations of NAA, Karim *et al.* (2006) obtained higher crude protein in chickpea seeds where the maximum was noted from 20 ppm NAA treatment. Ullah (2006) evaluated the effect of different concentrations of NAA (10, 30, 50, 70, 90 and 110 ppm) and reported that lower concentrations of NAA

(10, 30 and 50) had stimulating effect on the amount of protein content of seed of cowpea where, the highest amount was obtained from 50 ppm NAA but concentration exceeding the limit of 50 ppm found to have exactly opposite effect in producing less protein. Akter (2010) found both increase and decrease in protein content of maize grain due to 100 and 200 ppm of NAA respectively. Olaiya *et al*. (2010) carried out an experiment on tomato and found that the crude protein content was increased due to 60, 100 and 140 ppm NAA treatments. Report of Jahan and Adam (2014) revealed that protein content of grain of BRRI Dhan-29 and BRRI Dhan-50 increased due to both 100 and 200 ppm of NAA treatments where, the maximum increase was recorded from 100 ppm NAA in both the varieties. By applying NAA treatments (50, 70, 90 and 110 ppm), Noor *et al*. (2017) obtained significantly maximum crude protein in fresh and dry seeds of French bean following 50 ppm NAA treatment.

Although abundant investigations has been done on the effect of N-fertilizer on wheat crops around the world but existing report in relation to combined effect NAA and N-fertilizer is only one. Islam (2015) evaluated the effect of 25 and 50 ppm NAA in combination with varying N-levels (0, 50, 75 and 100% of recommended dose) on BARI Gom-26 and reported that all combined treatments resulted non-significantly higher protein content in grain. He recorded maximum protein content from 25 ppm NAA in combination with 75% N-level followed by 25 ppm in combination with 100% N-level. However in maize, Akter (2016) reported both increase and decrease in protein content of seeds following NAA treatments at varying N-levels (25 and 50 ppm in combination with recommended dose, 50, 100 and 150% higher dose).

2.7.6.3 Fat content of grain

Reports are available regarding the response of NAA on fat content of different crops except wheat. Karim *et al.* (2006) reported that NAA treatments had both stimulating and retarding effect on fat content in chickpea seeds. They obtained higher amount of fat from seeds of 10 and 30 ppm treatment although decreased following 20 ppm NAA treatment. Findings of Ullah (2006) revealed that lower concentrations (10, 30 and 50) of NAA increased the amount of fat content in cowpea seeds but when the concentration exceeded the limit of 50 ppm (70, 90 and 110 ppm), found to have exactly opposite effect in producing less fat. Akter (2010) showed that fat content of maize grain increased due to both 100 and 200 ppm of NAA application. Olaiya *et al*. (2010) noted law values for fat content in NAA (60, 100 and 140 mg per L) treated tomatoes. Outcome of Jahan and Adam (2014) revealed that fat content of two varieties of rice *viz.* BRRI Dhan-29 and BRRI Dhan-50 increased due to both 100 and 200 ppm NAA treatments where, the maximum increase was due to 100 ppm NAA treatment. Noor *et al*. (2017) reported that application of NAA treatments (50, 70, 90 and 110 ppm) significantly decreased crude fat of fresh pod and the minimum was recorded from 50 ppm treated plant. They also reported that crude fat content of French bean was increased progressively with the increasing in NAA concentration from 50 ppm but always lower than control treatment. But no report is available relating to the effect of NAA in combination with N-fertilizer on any cereal crop.

2.7.6.4 Starch content of grain

Published information is unavailable relating to the effect of NAA alone and in combination with N-fertilizers on starch content of any crop plant.

2.7.6.5 Moisture content of grain

Very limited number of reports are available regarding the effect of NAA on cereal crops. By applying NAA treatments, Akter (2010) showed that moisture content of maize grain decreased by 8.65 and 0.385 % due to 100 and 200 ppm respectively. Jahan and Adam (2014) also reported that application of 100 and 200 ppm NAA reduced moisture content of grain in two varieties of rice where, the maximum decrease was due to 100 ppm treatment in BRRI Dhan-50. Findings of Noor *et al*. (2017) revealed that application of NAA treatments slightly increased pod moisture of French bean where the highest value was noted from 50 ppm NAA followed by 70, 90 and 110 ppm respectively. No investigation has been found in relation to the response of NAA alone and in combination with N-fertilizer on wheat.

2.7.6.6 Crude fibre content of grain

Information relating to the effect of NAA is available on different crops other than wheat. Karim *et al.* (2006) reported that application of 10 ppm NAA increased the crude fibre content of dry seeds of chickpea but decreased following both 20 and 30 ppm. Outcome of Noor *et al*. (2017) revealed that various concentrations of NAA (50, 70, 90 and 110 ppm) treatments resulted significantly higher crude fibre content in fresh pod of French bean up to 90 ppm where, the maximum was found from 50 ppm treatment. But application of NAA in combination with N-fertilizer is unavailable on this aspect.

2.7.6.7 Ash content of grain

Although reports regarding the responses of NAA are available on different cereal grains but are lacking on wheat. Outcome of Akter (2010) revealed that foliar application of 100 and 200 ppm NAA had not any effect on ash content in maize grain. By applying 100 and 200 ppm, Jahan and Adam (2014) reported that ash content of two varieties of rice (BRRI Dhan-29 and BRRI Dhan-50) grain reduced following both the treatments where, the maximum reduction was due to 100 ppm NAA treatment in BRRI Dhan-29. Findings of other researchers also revealed that application of NAA treatments had both positive and negative effect on ash content depending on concentration of NAA and type of crops. Karim *et al.* (2006) obtained higher ash content in chickpea seeds due to different concentrations of NAA treatments (10, 20 and 30 ppm) where the maximum was found from seeds of 30 ppm NAA treatment. Report of Ullah (2006) showed that ash content of seed of cowpea decreased following the application of various NAA treatments (10, 30, 50, 70, 90 and 110 ppm). In tomato, Olaiya *et al*. (2010) reported about higher ash content in tomato following the application of 60, 100 and 240 ppm NAA treatments. Noor *et al*. (2017) showed that application of NAA treatments (50, 70, 90 and 110 ppm) had significant influences on ash content of fresh pod of French bean. They recorded maximum ash content from 50 ppm treatments where it was 38.37% higher than the control.

2.7.6.8 Total sugar content of grain

Research report is very scanty in relation to the effect of NAA alone or in combination with N-fertilizer on any crops including wheat. Upadhyay *et al.* (1993) reported that NAA (50 and 100 ppm) was effective in improving the sugar content of chickpea. By applying 25 and 50 ppm NAA, Ibrahim *et al.* (2007) obtained higher values of total soluble sugar content in seeds of faba bean due to 25 and 50 ppm NAA where, the increase was significant due to 25 ppm.

2.7.6.9 Reducing sugar content of grain

Investigation relating to the effect of NAA alone and in combination with N-fertilizer on wheat is unavailable. By applying 400 ppm of NAA, Jahan *et al.* (1992) found that reducing sugar of fruit of bitter gourd was increased at the edible stage.

2.7.7 Amino acid contents of grain

Effects of NAA treatments on amino acid contents in grain of different crops are available. Dhingra *et al.* (1995) found increased amino acids in chickpea seeds following the application of 20 ppm NAA. Deshai and Khanvilkar (1997) reported for Bengal gram that arginine, tryptophan, histidine, threonine and tyrosine contents were increased due to application of 100 ppm NAA . Findings of Karim *et al*. (2006) showed that aspartic acid, arginine, lysine, phenylalanine, serine, glycine and alanine contents of chickpea were increased following the application of NAA treatments (10, 20 and 30 ppm). Findings of them also showed that glutamic acid content was decreased due to all NAA treatments. However, leucine content was increased following 10 and 20 ppm NAA treatment but decreased following 30 ppm. In case of isoleucine, the same amount was obtained from both 10 and 30 ppm NAA although reduced due to 20 ppm. Results of Karim *et al*. (2006) revealed that higher content of valine and threonine in chick pea was recorded due to 10 ppm NAA only. Higher amount of tyrosine was also recorded from all NAA treatments except 10 ppm. By applying 40 and 50 ppm NAA treatments on cowpea, Ullah *et al*. (2011) obtained higher amount of glutamic acid, aspartic acid, lysine, arginine, valine, glycine, alanine and serine contents compared to the control. They obtained higher content of isoleucine from 50 ppm NAA whereas, equal amount was recorded from 40 ppm treatment. Their findings revealed that leucine, tyrosine, threonine and phenylalanine content reduced following the application of both 40 and 50 ppm NAA.

Noor *et al.* (2017) estimated fourteen amino acids content in dry French bean as influenced by different NAA treatments (50, 70, 90 and 110 ppm) and found increased lysine, aspartic acid, glutamic acid, arginine, serine and tyrosine contents following all treatments where, the maximum value was obtained from 50 ppm NAA except aspartic acid and serine contents. Findings of Noor *et al.* (2017) revealed that leucine, isoleucine, methionine, valine, histidine and glycine contents increased up to the application of 90 ppm NAA treatments where the maximum content was also noted from 50 ppm followed by 70 and 90 ppm respectively. Their report also revealed that concentration above 90 ppm had retarding effect on these amino acids content. The amino acids *viz.* threonine and alanine content was noted maximum from 50 ppm NAA application but decreased following rest of the treatments. But research finding is unavailable regarding the effect of NAA alone or in combination with N-fertilizer on amino acids profile on any cereal crops.

2.7.8 Enzyme activities of grain

The activities of hydrolytic enzymes, especially amylase, are important factors that may limit the utilization of cereals. Proteases hydrolyse the peptide linkage, releasing protein fragments or free amino acids. But, investigation relating to the response of NAA alone and in combination with N-fertilizer is not available on wheat. However, limited reports have been found on the effects of other plant growth regulators on amylase and protease activities of wheat grain. El-Feky and Abo-Hamad (2014) reported that the wheat seeds treated with different concentration of Brassinolide (0.1, 0.5 and 1.0 mg/L) have a gradual increase in both amylase and protease activities where the maximum performance was noted from 1 mg/L treatment.

2.7.9 Mineral contents of grain

A single report is available relating to the combined effect of NAA and N-fertilizer on NPK content of wheat grain where, application of 25 and 50 ppm NAA at varying nitrogen levels (50, 75 and 100% of recommended dose) had beneficial effect (Islam and Jahan 2016b). But, no report is available regarding the effect of NAA alone or in combination with N-fertilizer on Fe, Ca and Zn contents of wheat plants.

MATERIALS AND METHODS

Four field experiments were carried out for three consecutive years during the period from 2014 to 2017. First experiment was conducted with six high yielding varieties of wheat in four sowing time during 2014-2015 season for selection of the best performed variety and optimum sowing time. Second experiment was carried out in selected optimum time of 2015-2016 using different concentrations of Naphthalene acetic acid (NAA) as foliar spray in combination with various Nitrogen (N) levels on selected variety of wheat to find out better performing treatment for further studies. Third experiment was also carried out during 2015-2016 in selected optimum time with lower concentrations of NAA as seed soaking treatment in combination with the recommended dose of N-fertilizer to find out the suitable concentration. During 2016-2017 fourth experiment was carried out using best foliar treatment and selected seed soaking treatments in combination with varying N-levels at two sowing time (timely and 7 days late sown).

3.1 Experimental site

All experiments were conducted in the research field of the Botanical Garden of the Department of Botany, University of Dhaka. The experimental site is located at 23°40´-23°45´ N latitude and 90°20´-90°30´ E longitude having an altitude of 1.7-14 AMSL. Soil analysis were done at the laboratory of the Department of Soil Water and Environment of Dhaka University. The biochemical analyses were carried out in the Plant Physiology, Biochemistry and Nutrition Laboratory of the Department of Botany and partly in the Department of Soil Water and Environment of the University of Dhaka and also in Bangladesh Council of Scientific and Industrial Research (BCSIR).

3.2 Experimental Materials

3.2.1 Plant Materials

Six high yielding varieties of wheat *viz.* BARI Gom-23, BARI Gom-24, BARI Gom-25, BARI Gom-26, BARI Gom-27 and BARI Gom-28 were used as plant material. Seeds of all varieties were collected from Bangladesh Agricultural Research Institute (BARI). All the varieties were developed by wheat research centre, BARI.

3.2.1.1 BARI Gom-23

BARI Gom-23 is suitable to grow all over the country except saline areas and was developed in 2005. This variety is also known as Bijoy. It's highly tolerant to Bipolaris leaf blight and resistant to leaf rust diseases and moderately tolerant to terminal heat stress. The average yield ranged from 4300-5000 kg/ha and gives 10-20% higher yield under late seeding (Chowdhury and Hassan 2013).

3.2.1.2 BARI Gom-24

BARI Gom-24 was developed in 2005 and has similar characteristics features like BARI Gom-23 but suitable for growing under both optimum and late sown conditions. This variety is also known as Prodip and the average yield ranged from 4300-5100 kg/ha (Chowdhury and Hassan 2013).

3.2.1.3 BARI Gom-25

BARI Gom-25 is suitable to grow well all over the country and in moderate saline area. It can be grown under both optimum and late seeding conditions. This variety was developed in 2010 having an average yield of 3800-5200 kg/ha. The genotype also showed moderate degree of resistance to stem rust race (Chowdhury and Hassan 2013, Azad *et al.* 2017).

3.2.1.4 BARI Gom-26

BARI Gom-26 is also suitable for growing both in optimum and late seeding condition. It can also be grown successfully throughout the country except in areas with salinity level less than 6 dS/m (Chowdhury and Hassan 2013). This variety was released in the year of 2010. The average yield of this variety is 4000-5500 kg/ha and gives 10-12% higher yield under late seeding condition (Azad *et al.* 2017).

3.2.1.5 BARI Gom-27

BARI Gom-27 can be grown all over the Bangladesh except areas of sourthern belt with salinity level more than 8 dS/m and was released in the year of 2012. The average yield of this variety is 3500-5400 kg/ha (Azad *et al.* 2017).

3.2.1.6 BARI Gom-28

BARI Gom-28 was released in the year of 2012. The average yield is 4500-5500 kg/ha. In addition, the variety gives 15-20% higher yield than other varieties in case of sowing beyond optimum time (Chowdhury and Hassan 2013, Azad *et al.* 2017).

3.2.2 Plant growth regulator

Naphthalene acetic acid (NAA), a synthetic auxin was used as plant growth regulator in this investigation. It was used as a salt of 1-napthyl acetic acid. It was being marketed here by LOBA Chemie Pvt. Ltd. Mumbai, India. Chemical formula of NAA is $C_{12}H_{10}0_2$. Molecular weight and melting point of the chemical is 186.21 and 128-131^{o} C respectively.

3.2.3 Fertilizer

Fertilizer used in the present investigation were Urea, Muriate of Potash (MP), Gypsum, Boric acid and Zinc sulphate. All the fertilizers were purchased from local market.

3.2.4 Soil

The soil of the experimental field was a clay loam having pH 6.80. The values for the initial soil analysis are as follows:

Organic Carbon (%)	: 9.49
Total Nitrogen (%)	: 0.111 (Optimum = 0.271-0.360)
Available Phosphorus (µg/g)	: 84.28 (High = 15.10-18.75)
Available Potassium (meq/100g)	: 0.037 (Optimum = 0.226-0.300

Soil was analysed before set up of each experiment.

3.2.5 Sowing time

Optimum time for wheat is very important due to its own definite requirements for temperature and light for emergence, growth and flowering (Dabre *et al.* 1993). In the first experiment growth and yield performances of six varieties of wheat were evaluated in relation to four sowing time *viz.* November 15, 22, 29 and December 04.

Second and third experiment was conducted using selected variety of wheat at most suitable sowing time *viz.* November 15. In case of fourth experiment, effects of selected NAA concentrations in combination with different nitrogen levels on the selected variety of wheat has been investigated in two sowing time *viz*. timely sown (November 15) and 7 days late sown (November 22).

3.3 Methods

Field experiments were carried out at the Botanical Garden, Department of Botany, University of Dhaka. The initial experiment was designed for selection of the best performed variety and optimum sowing time. For other experiments, NAA was applied both as foliar and seed soaking treatments in combination with different doses of N-fertilizers.

3.3.1 Quantitative determination of chemical and physical characteristics of soil

The experimental soil was transported to the laboratory in polythene bags and spread on to polythene sheets to allow them to dry. Organic debris and stones were removed carefully. Soil was analyzed before the setup of each experiment.

3.3.1.1 Soil reaction (pH)

The pH of soil (field moisture condition) was determined by using a glass electrode. The reaction of soil to water was 1.0: 2.5 as suggested by Jackson (1958).

3.3.1.2 Determination of total Nitrogen

The Kjeldal method was followed for the digestion of soil samples and the ammonium content of the digest was determined by steam distillation using a Hoskins apparatus as described by Marr and Cresser (1983).

3.3.1.3 Determination of Phosphorus

To determine the amount of phosphorus (P) of soil, Bray and Kurtz (1945) method was used as this method has been most successful on acid soils. The colour of phosphorus was developed by ascorbic acid blue colour method (Murphy and Riley 1962).

3.3.1.4 Determination of Potassium

Ammonium acetate method was used to determine the amount of potassium (K). Potassium was extracted with 1M neutral ammonium acetate solution and the potassium content in the extract was determined by flame photometer.

3.3.3 Experimental design and field layout

The experiment was laid out in a Randomized Block Design (RBD) with four replications**.** The total area of experimental field was 98.56 m^2 which was divided into 4 subplots. Measurement of experimental field were as-

Dimension of field	= 17.60 m × 5.60 m
Subplot to subplot distance	= 50 cm
Row to row distance in subplot	= 20 cm
Plant to plant distance in a row	= 10 cm

3.3.4 Land preparation

The land was prepared by repeated spading and was labelled by laddering. Chemical fertilizers were applied during land preparation.

3.3.5 Seed sterilization

Seeds were washed thoroughly with tap water and then surface sterilized by 0.5% calcium hypochlorite [$Ca(OCl)_2$] solution for five minutes. The seeds were then repeatedly washed in distilled water to remove any trace of calcium hypochlorite.

3.3.6 Seed sowing

For experiment 1, after sterilization seeds of six varieties of wheat were sown in four different sowing time *viz.* November 15, 22, 29 and December 04 in rows. For experiments 2 and 3, seeds were sown in November 15 and for experiments 4, seeds were sown in two sowing time *viz.* November 15 (timely sown) and 22 (7 days late sown).

3.3.6 Naphthalene acetic acid (NAA)

Naphthalene acetic acid was applied in two different methods *viz.* foliar spray and seed soaking treatments.

3.3.6.1 Seed soaking

In case of seed soaking treatment (experiments 3 and 4), seeds were soaked in respective NAA solutions separately for 12 hours whereas seeds of other treatments were soaked in distilled water.

3.3.6.2 Foliar spray

Foliar spray of respective treatments were done in sunny early morning at the age of 30 days in case of experiment 2 and 4. Aqueous NAA solution was mixed with appropriate proportion of Tween-20 (Polyoxyethylene 20 sorbitan monolaurate) as wetting agent before spraying. A hand sprayer was used to spray the solution of different concentrations on the foliage of wheat plants till to drip. The control plants were sprayed with distilled water. Spraying was done in the early hour of morning to avoid intense light effect that might make the hormone inactive or other harmful effects that might be caused due to dehydration during peak metabolic hour. During spraying, precautionary measures were taken to avoid mixing of NAA from one treatment to another.

3.3.7 Fertilizer application

Doses of all fertilizers were selected from the fertilizer requirement of the soil as recommended in the Fertilizer Recommendation Guide (2012). The fertilizer requirement of the soil was calculated from the initial analysis of the NPK contents of the soil. In case of experiment 1and 3, all fertilizers were applied as par recommended doses. But there were five N levels (0, 25%, 50%, 75% and 100%) in case of experiment 2 and 4. After each experiment, soils were analyzed for NPK content and on the basis of analysis the required fertilizer doses for the next experiment were calculated. Two-third of urea (as a source of N-fertilizer) and entire amount of other fertilizers (muriate of potash, gypsum, zinc sulphate, boron) were applied as basal dose during final land preparation. The remaining urea was applied immediately after the first irrigation. Cow-dung was also mixed homogenously during land preparation.

3.3.8 Cultural practices

Cultural practices *viz.* thinning, irrigation, weeding etc. were done following Hand Book of Agricultural Technology (Chowdhury and Hassan 2013). Thinning and weeding were done at 15 days after emergence of seedlings maintaining plant to plant distance of 10 cm. It was made in such a way that healthy seedlings of uniform size and vigor were allowed to grow. Irrigation was done twice at 18 and 55 days after sowing.

3.3.9 Treatments

There were altogether twenty four treatments in case of experiment 1 with two factors *viz.* variety (A) and sowing time (B). Experiment 2 was conducted with two factors *viz.* NAA and N-fertilizer and there were altogether thirty five treatments. Experiment 3 was carried out with four treatments. Experiment 4 consisted of nine treatments only. The number of treatments were reduced in the light of the results obtained in the previous three experiments.

Under factor (A), for the experiment 1 there were six varietal treatments as follows:

V_1 = BARI Gom-23

V_2 = BARI Gom-24

V_3 = BARI Gom-25

V_4 = BARI Gom-26

V_5 = BARI Gom-27

V_6 = BARI Gom-28

Under factor (B), for the experiment 1 there were four sowing time treatments as follows:

S_1 = Seed sown on November 15

S_2 = Seed sown on November 22

S_3 = Seed sown on November 29

S_4 = Seed sown on December 04

For the experiment 2, there were seven foliar spray treatments of NAA as follows:

SS_0 = Foliar spray of distilled water (without NAA)

SS_1 = Foliar spray of 10 ppm NAA

SS_2 = Foliar spray of 20 ppm NAA

SS_3 = Foliar spray of 30 ppm NAA

SS_4 = Foliar spray of 40 ppm NAA

SS_5 = Foliar spray of 50 ppm NAA

SS_6 = Foliar spray of 60 ppm NAA

In experiment 2, there were also five levels of N-fertilizer treatments as follows:

F_0 = Without any application of urea

F_1 = 25% of the recommended dose of urea

F_2 = 50% of the recommended dose of urea

F_3 = 75% of the recommended dose of urea

F_4 = 100% of the recommended dose of urea

In case of experiment 3, there were four seed soaking treatments of NAA all in combination with the recommended dose of N-fertilizer *viz.*

SO_0 = Seed soaked in distilled water (without NAA)

SO_1 = Seed soaked in 10 ppm NAA

SO_2 = Seed soaked in 20 ppm NAA

SO_3 = Seed soaked in 30 ppm NAA

Experiment 4 consisted of nine treatments evaluated under two sowing time (November 15 and 22) as follows:

Control = Without application of NAA and urea

F_4 = Recommended dose of urea

SOF_0 = Seed soaking with 10 ppm NAA+without application of urea

SOF_1 = Seed soaking with 10 ppm NAA+25% of the recommended dose of urea

SOF_2 = Seed soaking with 10 ppm NAA+ 50% of the recommended dose of urea

SOF_3 = Seed soaking with 10 ppm NAA+ 75% of the recommended dose of urea

SOF_4 = Seed soaking with 10 ppm NAA+100% of the recommended dose of urea

SSF_0 = Foliar spray of 20 ppm NAA+ without application of urea

SSF_1 = Foliar spray of 20 ppm NAA + 25% of the recommended dose of urea

3.4 Experimental observation and data collection

To study the sequence of physiological and biochemical changes, the characteristics studied at different stages of growth and development of plants are given below:

3.4.1 Physiological parameters

The following experimental observations and determinations were made during the different growth phases of plants. A total number of twelve (three from each replication) plants were randomly selected to record data on following parameters.

3.4.1.1 Plant height

Height of plants in cm was measured at an interval of 15 days from the age of 30 days after sowing (DAS) till harvest.

3.4.1.2 Number of tillers per plant

Number of tillers per plant was recorded at an interval of 15 days starting from 30 days after sowing (DAS) till harvest.

3.4.1.3 Number of leaves per plant

Number of leaves per plant was counted at an interval of 15 days from the age of 30 DAS up to harvest.

3.4.1.4 Total dry matter per plant

Plants of different treatments were harvested separately at an interval of 15 days from the age of 30 DAS up to harvest. By gentle agitation in water, soil was shaken off from the roots. The roots were further cleaned by carefully washing. The excess water was blotted against blotting paper and then the weight of total dry matter was taken after oven drying the materials at 80 ^{0}C till constant weight was attained.

3.4.2 Yield attributes and yield

Data on yield contributing characters help to assess the productivity of a crop. A good relationship exists between yield components and yield. The grain yield is the ultimate outcome of the contribution of different physio-morphological characters. The yield contributing characters were studied as follows:

3.4.2.1 Number of effectives tillers (spikes) per plant

Number of effective tillers per plant was counted at harvest.

3.4.2.2 Number of non-effectives tillers per plant

Number of non-effective tillers per plant was recorded at harvest.

3.4.2.3 Length of spike

Length of spike was measured in cm after harvest.

3.4.2.4 Dry weight of spikes

Harvested spikes were oven-dried at 40 ^{0}C for 48 hours and their dry weight (g) were recorded.

3.4.2.5 Number of grains per spike and per plant

Number of grains per spike was counted after harvest.

3.4.2.6 Weight of 1000-grains

After harvesting and drying, weight of 1000-grains (g) were recorded.

3.4.2.7 Yield per plant and per hectare

Yield per plant was calculated according to the formula of ICRISAT (1992). Yield plant^{-1} = (Spike plant^{-1}) × (Spikelets spike^{-1}) × (Seed weight).

Whereas, yield per hectare was calculated by multiplying the value of yield per plant with the number of plants in a hectare area.

3.4.2.8 Harvest index (HI)

Harvest index was calculated by the empirical formula given below:

$$HI = EY / BY \times 100$$

Where,

EY = Economic yield i.e. grain yield

BY = Biological yield i.e. total dry matter produced by the plant (g).

3.4.3 Biochemical parameters

Biochemical parameters were investigated in case of experiment 2, 3 and 4. Pigment content of leaves of three different stages *viz.* tillering, flowering and grain filling were investigated in experiment 2, 3 and 4. Nitrogen (N), phosphorus (P) and potassium (K) contents, NPK uptake and Nitrogen use efficiency (NUE) of shoot and root were analysed at three different stages *viz.* flowering, grain filling and harvest of experiment 4. The NPK content, uptake and NUE of grains of experiment 4 were also analysed after harvest. For comparative analysis of three selected treatments of experiment 4 (Control, recommended dose of N-fertilizer, best performed treatment), nutritional parameters, amino acids contents, enzyme activities and some mineral contents of grain has been analysed.

3.4.3.1 Quantitative determination of pigment contents of leaves

Chlorophyll a (chl. a), Chlorophyll b (chl. b) and total carotenoids contents of leaves were determined for each treatment at vegetative, flowering and grain filling stages. The analysis of pigments was determined spectrophotometrically. The amount of chl. a and b were determined by using specific absorption co-efficient of McKinney (1940) and the formulae of Maclachalan and Zalik (1963).

The formulas used are as follows:

$$\text{Chl. a} = \frac{(12.3\ D_{663} - 0.86\ D_{645})\ V}{d \times 1000 \times W}\ \text{mg/g fresh weight}$$

$$\text{Chl. b} = \frac{(19.3\ D_{645} - 3.6\ D_{663})\ V}{d \times 1000 \times W}\ \text{mg/g fresh weight}$$

Where,

D = Optical density at wave length indicated

V = Final volume of the extract

W = Fresh weight of leaf material used

d = length of light path in cm.

The amount of carotenoids were determined by the equation of von Wettstein (1957). The equation used is as follow:

$$C_c = 4.695\ D_{440.5} - 0.268C\ (a+b)$$

Where,

Cc = Concentration of carotenoids in mg/L

The carotenoids content was then converted to mg/g fresh leaf weight

3.4.3.2 Quantitative determination of N, P and K contents of shoot, root and grain

Nitrogen (N), phosphorus (P) and potassium (K) contents were determined in the digest of dried plant material following Jackson (1973). Phosphorus was determined by colorimetric method with ammonium paramolybdate and ascorbic acid reagent at 882 nm and potassium by flame photometer at 767 nm.

3.4.3.3 Quantitative determination of N, P and K uptake by shoot, root and grain

Uptake of N, P and K were calculated using the formula (Nyborg *et al.* 1995) given below:

$$\text{Uptake of N/P/K} = \frac{\text{\% N/P/K obtained}}{100} \times \text{dry weight}$$

3.4.3.4 Quantitative determination of Nitrogen use efficiency (NUE) of shoot, root and grain

The NUE of shoot, root and grain were calculated using the formula of Nyborg *et al.* (1995).

$$\text{NUE} = \frac{F_n - F_0}{\text{N added}}$$

Where, F_n = N uptake at given fertilizer

F_0 = N uptake at control

3.4.3.5 Quantitative determination of nutritional parameters of grain

Carbohydrate, protein, fat, starch, moisture and ash content of grain were determined following the method as described in 'A Manual of Laboratory Techniques' (Anonymous 1976). Crude fibre content of grain was determined following the method of AOAC (2000). Total sugar and reducing sugar content of grain were estimated according to Ranganna (1991).

3.4.3.6 Quantitative determination of mineral contents of grain

Minerals *viz.* N, P, K, Fe (Iron), Ca (Calcium) and Zn (Zinc) contents of wheat grain were determined by the method as described in 'A manual of Laboratory Techniques' (Anonymous 1976).

3.4.3.7 Estimation of amino acid contents of grain

Amino acids *viz. viz*. aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, histidine, lysine and arginine were analyzed by amino acid analysis system instruction manual (Anonymous 1993).

3.4.3.8 Quantitative determination of enzyme activities of grain

Wheat grains (0.5 g) were grinded in a mortar with 0.1M phosphate buffer with respective pH (amylase 6.7 and protease pH 5.5) and finally crushed into paste using a homogenizer. The temperature was maintained at 4^0C by putting ice in the outer chamber of the homogenizer. The suspension was then filtered through few layers of cheese cloth in cold room. The filtrate was then collected and clarified further by centrifuged at 10,000 rpm for 15 min at 4^0C.

3.4.3.8.1 Amylase activity of grain

Amylase activity of grain was assayed following the method as described by Jayaraman (1981).

3.4.3.8.2 Protease activity of grain

Protease activity of grain was assayed following the modified method as describe by Mahadehvan and Sridhar (1982).

3.5 Statistical analysis

Data collected on different parameters were statistically analyzed and treatment means were compared by least significant difference test (Steel *et al.* 1997).

RESULTS

In this chapter results of four experiments have been presented separately. For simplification and to avoid repetition, only the treatments and treatment combinations have been used instead of different concentrations or methods of NAA application, different levels of N-fertilizer application or their combination treatments. Results of each experiment have been presented under three sub headings as physiological parameters, yield attributes and yield and biochemical parameters. In the tables, the mean values of different parameters obtained under different treatments have been presented whereas, in the texts and figures the percentage increases and decreases indicate in relation to corresponding control plant values have been shown. Statistical analysis have been done and in the tables, means in a column followed by the same letter do not differ significantly at 5% level. To avoid repetitions, in all the chapter ppms have been deleted and thus 10 ppm NAA has been written as 10 NAA and so on.

4.1 Experiment 1 carried out during the season of 2014-2015

Experiment 1 was conducted to evaluate the effect of four sowing time on physiological and yield parameters of six high yielding varieties of wheat for selection of the best performed variety and optimum sowing time. In this experiment in the texts, tables and figures V_1, V_2, V_3, V_4, V_5 and V_6 represent BARI Gom-23, BARI Gom-24, BARI Gom-25, BARI Gom-26, BARI Gom-27 and BARI Gom-28 respectively. The treatments indicated herein as S_1, S_2, S_3 and S_4 represent seed sown on November 15, 22, 29 and December 04 respectively. There were twenty four combination treatments and those have been represented as V_1S_1, V_2S_1, V_3S_1, V_4S_1, V_5S_1, V_6S_1, V_1S_2, V_2S_2, V_3S_2, V_4S_2, V_5S_2, V_6S_2 and so on.

4.1.1 Effects of sowing time on physiological parameters

4.1.1.1 Plant height

Plant height was measured at six different ages starting from 30 days after sowing (DAS) up to harvest and have been presented in Table 4.1a and 4.Ib. Different varieties and sowing time had both significant and non-significant responses on wheat.

Variety

Height of six varieties of wheat were affected both significantly and non-significantly at different ages (Table 4.Ia). At the age of 30 DAS, the maximum height (36.26 cm) was recorded from V_6 which was significantly higher than all the varieties except V_4. At 45 DAS, plant height ranged from 39.51-48.51 cm where, the tallest plant was also obtained from V_6 but was significantly higher than V_1 and V_5. At 60 DAS, significantly tallest plant was obtained from variety, V_2 and at this DAS the shortest plants were recorded from V_6 treatment. After this period the maximum plant height was also noted from V_2 up to harvest. Height recorded from V_2 at the age of 75 DAS was significantly higher than V_4 and V_6. But at 90 DAS and at harvest height of V_2 differ significantly from V_6 only. However, from 75 DAS up to harvest the height of plant was found lowest from V_6.

Sowing time

Sowing time had both significant and non-significant influences on height of wheat plant at early ages (30-60 DAS). The tallest plants were obtained from S_3 treatment at all the ages whereas, the shortest plants were recorded from S_1 except at 30 and 45 DAS (Table 4.Ia). At the age of 30 DAS, plant height obtained from S_3 treatment was significantly higher than S_1 and S_4 treatments. Plant height at 45 DAS recorded from S_3 treatment (48.80 cm) was significantly higher than S_4 (42.18 cm) whereas, at the age of 60 DAS it was significantly higher than S_1 and S_2 treatments. After the age of 60 DAS sowing time had statistically similar response on height of different wheat varieties. Among the four sowing times, S_1 resulted shortest plant from the age of 60 DAS up to harvest.

Combined treatments

Significant and non-significant variations in plant height were observed due to combined treatments at all the ages (Table 4.Ib). At the age of 30 DAS, the maximum plant height (37.61 cm) was recorded from V_6S_2 treatment which was significantly different from rest of the treatments except V_6S_1, V_2S_2, V_4S_3 and V_6S_3. Plant height at the age of 45 DAS was recorded maximum from V_6S_3 treatment and it statistically identical to V_4S_1, V_6S_1, V_6S_2, V_2S_3, V_3S_3 and V_4S_3 treatments but different from rest of the treatments. From the age of 60 DAS up to harvest V_2S_3 resulted tallest plant.

Table 4.Ia. Effects of sowing time on plant height (cm) of six varieties of wheat at different ages during 2014-2015 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Variety (V)						
V_1	32.07 cd	43.22 bc	71.52 b	88.02 ab	89.68 a	90.04 a
V_2	33.69 b-d	46.79 ab	79.28 a	91.44 a	92.33 a	92.63 a
V_3	34.22 bc	45.13 ab	73.09 b	89.80 ab	91.42 a	91.68 a
V_4	35.22 ab	48.39 a	72.80 b	87.45 b	88.67 ab	89.08 ab
V_5	31.60 d	39.51 c	66.89 c	88.24 ab	90.33 a	90.70 a
V_6	36.26 a	48.51 a	72.16 b	83.53 c	84.43 b	84.97 b
Sowing time (S)						
S_1	33.13 bc	45.48 ab	72.18 b	86.62 a	87.80 a	88.08 a
S_2	35.29 ab	44.56 ab	68.58 b	87.44 a	89.95 a	90.23 a
S_3	35.53 a	48.80 a	76.96 a	90.36 a	91.27 a	91.70 a
S_4	31.42 c	42.18 b	72.77 ab	87.89 a	88.87 a	89.40 a
CV (%)	9.82	12.68	9.09	5.56	6.06	5.78
LSD (0.05)	2.25	4.29	4.59	3.74	4.59	4.37

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.Ib. Combined effects of variety and sowing time on plant height (cm) of wheat at different ages during 2014-2015 season.

Treatments (V × S)	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
V_1S_1	31.71 h-j	43.01 f-i	68.29 jk	83.25 ij	86.24 gh	86.80 g-i
V_2S_1	30.63 ij	44.36 e-i	75.99 b-e	87.35 d-h	88.34 d-h	88.61 e-i
V_3S_1	32.50 g-i	45.80 c-g	71.43 e-k	87.99 c-g	88.65 c-h	88.73 d-i
V_4S_1	34.25 d-g	49.61 a-c	73.49 c-g	86.24 e-i	86.70 f-h	87.13 g-i
V_5S_1	32.76 f-i	41.90 g-i	69.60 g-k	89.66 b-e	90.73 a-g	90.83 a-g
V_6S_1	36.93 a-c	48.19 a-e	74.26 c-f	85.24 f-i	86.18 gh	86.39 hi
V_1S_2	33.04 e-h	42.36 g-i	68.44 i-k	87.73 d-g	89.54 b-g	89.54 c-h
V_2S_2	36.14 a-d	47.80 b-f	76.33 b-d	92.71 ab	92.89 a-d	93.06 a-d
V_3S_2	35.24 b-e	44.49 d-i	70.53 f-k	89.70 b-e	93.81 ab	94.06 ab
V_4S_2	36.99 a-c	47.40 b-f	67.46 k	84.56 g-i	87.44 f-h	87.75 f-i
V_5S_2	32.73 f-i	37. 20 j-k	59.93 l	86.19 e-i	91.89 a-e	92.33 a-e
V_6S_2	37.61 a	48.11 a-f	68.83 h-k	83.74 h-j	84.14 h-i	84.63 ij
V_1S_3	33.80 e-h	47.03 b-f	76.34 b-d	90.16 b-d	91.00 a-f	91.60 a-f
V_2S_3	34.93 c-f	50.88 ab	84.63 a	94.00 a	94.84 a	94.91 a
V_3S_3	36.64 a-c	48.74 a-d	77.14 b-d	92.90 ab	93.64 ab	93.93 ab
V_4S_3	37.43 ab	51.32 ab	77.44 bc	90.61 a-d	91.53 a-e	91.95 a-f
V_5S_3	32.98 f-h	42.68 g-i	70.58 f-k	89.44 b-e	90.18 b-g	90.58 a-h
V_6S_3	37.44 ab	52.19 a	75.64 b-e	85.08 f-i	86.44 f-h	87.10 g-i
V_1S_4	29.74 jk	40.48 i-k	73.01 c-i	90.93 a-d	91.96 a-e	92.23 a-e
V_2S_4	33.06 e-h	44.13 e-i	80.20 a	91.71 a-c	93.24 a-c	93.81 a-c
V_3S_4	32.49 g-i	41.48 h-j	73.26 c-h	88.60 c-f	89.56 b-g	90.03 b-h
V_4S_4	32.20 g-i	45.21 d-h	72.80 d-j	88.39 c-f	89.00 c-g	89.49 c-h
V_5S_4	27.94 k	36.25 k	67.45 k	87.66 d-g	88.51 d-h	89.08 d-h
V_6S_4	33.08 e-h	45.55 c-h	69.91 f-k	80.08 j	80.95 i	81.78 j
CV (%)	9.82	12.68	9.09	5.56	6.06	5.78
LSD (0.05)	2.25	4.29	4.59	3.74	4.59	4.37

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

At the age of 60 DAS, height recorded from V_2S_3 treatment (84.63 cm) was significantly higher than all the treatments except V_2S_4 treatment (80.20 cm). At 75 DAS, V_2S_3 treatment also resulted significantly taller plant than most of the treatments except V_2S_2, V_3S_3, V_4S_3 V_1S_4 and V_2S_4. From 30-60 DAS the shortest plants were obtained from V_5S_4 treatment. Height obtained from V_2S_3 treatment at the age of 90 DAS and at harvest were significantly maximum although statistically similar to V_5S_1, V_2S_2, V_3S_2, V_5S_2, V_1S_3, V_3S_3, V_4S_3, V_1S_4, V_2S_4 treatments in both ages and also due to V_5S_3 treatment at harvest. At these two ages the minimum height was also noted from V_6S_4 treatment.

4.1.1.2 Number of tillers per plant

Number of tillers produced by plants were counted at six different ages starting from 30 DAS to harvesting. The mean values of number of tillers per plant during the investigation are presented in Table 4.IIa and Table 4IIb.

Variety

Number of tillers per plant of wheat were significantly influenced at all ages of growth except at 90 DAS. The maximum number of tillers per plant was obtained from the variety, V_5 from the age of 30 up to 90 DAS (Table 4.IIa). At the age of 30 DAS, number of tillers per plant of different varieties ranged from 2.16-3.31 where, significantly highest number was recorded from V_5 followed by V_1 and V_4 respectively. Maximum number of tillers per plant produced by V_5 (6.97) at 45 DAS was significantly higher than V_2 (5.77) only. At the age of 60 DAS, the highest number of tillers per plant produced by V_5 was statistically similar to V_1 and V_4 but significantly different from rest of the varieties. The maximum number of tillers (11.41) obtained from V_5 at 75 DAS was significantly higher than those of the variety V_3 (9.53). At the age of 90 DAS statistically identical number of tillers per plant was recorded from all the varieties. At harvest, the highest number of tillers per plant (7.13) was recorded from V_1 which was statistically similar to V_6 (6.75) but different to rest of the varieties (V_2, V_3, V_4 and V_5).

Sowing time

Number of tillers per plant were significantly influenced by different sowing times at all ages with an exception of 90 DAS.

Table 4.IIa. Effects of sowing time on number of tillers per plant of six varieties of wheat at different ages during 2014-2015 season.

Treatments	Age of plant in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Variety (V)						
V_1	2.72 b	6.56 ab	9.94 ab	10.59 ab	9.75 a	7.13 a
V_2	2.16 c	5.77 b	9.34 b	9.88 ab	8.94 a	5.47 c
V_3	2.31 bc	6.16 ab	8.75 b	9.53 b	9.00 a	6.38 b
V_4	2.66 b	6.17 ab	9.84 ab	10.88 ab	9.69 a	6.25 b
V_5	3.31 a	6.97 a	11.09 a	11.41 a	9.84 a	6.31 b
V_6	2.56 bc	6.02 ab	9.69 b	10.47 ab	9.66 a	6.75 ab
Sowing time (S)						
S_1	3.10 a	7.88 a	11.25 a	11.90 a	10.44 a	7.83 a
S_2	2.19 b	5.91 b	9.31 b	10.29 ab	9.13 a	6.96 b
S_3	3.10 a	6.73 b	9.58 b	10.13 b	9.40 a	5.94 c
S_4	2.08 b	4.58 c	8.96 b	9.52 b	8.96 a	4.79 d
CV (%)	13.88	9.44	10.76	10.31	13.99	13.87
LSD (0.05)	0.43	1.14	1.35	1.67	2.08	0.71

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.IIb. Combined effects of variety and sowing time on number of tillers per plant of wheat at different ages during 2014-2015 season.

Treatments (V×S)	Age of plant in days after sowing (DAS)					At harvest
	30	45	60	75	90	
V_1S_1	2.50 g-i	7.06 c-e	10.13 d-f	11.13 ab	10.38 ab	8.25 a
V_2S_1	2.38 g-i	5.94 f-h	9.00 f-i	9.75 b-g	9.75 b-d	6.88 c-e
V_3S_1	3.50 c	9.25 a	12.25 ab	12.50 a	12.13 a	8.38 a
V_4S_1	3.25 cd	8.38 ab	11.88 bc	11.38 ab	10.63 ab	7.75 ab
V_5S_1	4.00 b	9.00 a	13.50 a	11.00 a-c	9.88 bc	8.25 a
V_6S_1	3.00 d-f	7.63 bc	10.75c-e	10.13 b-f	9.88 bc	7.50 bc
V_1S_2	2.75 e-g	6.31 fg	10.25 d-f	10.13 b-f	9.25 b-f	7.88 ab
V_2S_2	2.13 i-k	7.06 c-e	11.00 b-d	9.88 b-f	9.13 b-f	6.25 ef
V_3S_2	1.63 l	5.44 g-i	8.25 h-j	8.63 f-j	8.88 b-f	7.38 bc
V_4S_2	2.13 i-k	5.69 f-h	7.88 i-k	8.88 f-i	8.13 c-f	6.38 d-f
V_5S_2	2.13 i-k	5.06 h-j	7.88 i-k	9.25 d-h	9.13 b-f	6.88 c-e
V_6S_2	2.38 g-i	5.88 f-h	9.50 e-h	10.75 b-d	10.25 ab	7.00 cd
V_1S_3	3.13 c-d	7.44 b-d	10.38 de	10.00 b-f	10.13 a-c	6.88 c-e
V_2S_3	2.25 h-j	6.00 f-h	7.75 i-k	7.63 h-j	7.63 ef	4.38 jk
V_3S_3	2.38 g-i	5.56 f-h	6.88 k	7.63 h-j	7.25 f	5.00 h-j
V_4S_3	3.13 c-e	6.38 d-g	11.00 bd	9.00 e-i	10.38 ab	5.50 gh
V_5S_3	4.50 a	8.38 ab	11.13 b-d	9.38 c-g	10.63 ab	6.00 fg
V_6S_3	3.25 cd	6.63 c-f	10.38 de	10.63	10.38 ab	7.88 ab
V_1S_4	2.50 g-i	5.44 g-i	9.00 f-i	8.88 f-i	9.25 b-f	5.50 gh
V_2S_4	1.88 j-l	4.06 j	9.63 e-g	7.38 ij	9.25 b-f	4.38 jk
V_3S_4	1.75 kl	4.38 ij	7.63 jk	7.13 j	7.75 d-f	4.75 i-k
V_4S_4	2.13 i-k	4.25 j	8.63 g-j	9.38 c-g	9.63 b-e	5.38 g-i
V_5S_4	2.63 f-h	5.44 g-i	10.25 d-f	7.38 ij	9.75 b-d	4.13 k
V_6S_4	1.63 l	3.94 j	8.63 g-j	8.13 g-j	8.13 c-f	4.63 jk
CV (%)	13.88	9.44	10.76	10.31	13.99	13.87
LSD (0.05)	0.43	1.14	1.35	1.67	2.08	0.71

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Sowing time, S_1 produced maximum number of tillers per plant throughout the growth period whereas, S_4 produced the minimum number (Table 4.IIa). At the age of 30 DAS, number of tillers per plant obtained from different sowing time ranged from 2.08-3.10 where, significantly highest number (3.10) was recorded from both S_1 and S_3 treatments followed by S_2 (2.19) and S_4 (2.08) respectively. At 45 and 60 DAS significantly maximum number of tillers per plant was recorded from S_1 treatment followed by S_3, S_2 and S_4 treatments respectively. Number of tillers per plant obtained at 60 DAS also showed similar trend as recorded from 45 DAS. At 75 DAS, number of tillers per plant gradually decreased with delayed sowing where, S_1 treatment had significantly higher number of tillers per plant than S_3 and S_4 treatment. Number of tiller per plant obtained at the age of 90 DAS ranged from 8.96-10.44 although all sowing times had statistically identical number of tillers at this stage. At harvest, number of tillers per plant significantly decreased with delayed sowing time.

Combined treatments

Number of tillers per plant was both significantly and non-significantly influenced by combined treatments of variety and sowing time at different ages (Table 4.IIb). At the age of 30 DAS, significantly maximum number of tillers per plant (4.50) was recorded from V_5S_3 followed by V_5S_1 (4.00) and V_3S_1 (3.50) treatments respectively. Number of tillers obtained at the age of 45 DAS ranged in between 3.94-9.25 where, maximum value was noted from V_3S_1 treatment which was statistically similar to V_4S_1, V_5S_1 and V_5S_3 treatments but significantly different from all other treatments. At 60 DAS, V_5S_1 treatment resulted significantly highest number of tillers per plant but statistically similar to only V_3S_1 treatment. At the age of 75 DAS, V_3S_1 produced highest number of tillers per plant and significantly differ from all other treatments except V_1S_1, V_4S_1 and V_5S_1 treatments. At 90 DAS, the maximum number of tillers per plant was recorded from V_3S_1 which significantly higher than all treatments except V_1S_1, V_4S_1, V_6S_2, V_1S_3, V_4S_3, V_5S_3 and V_6S_3. At harvest, number of tillers per plant obtained from different combined treatments ranged from 4.13-8.38 where, V_3S_1 also produced significantly maximum value but statistically not different from V_1S_1, V_3S_1, V_4S_1, V_5S_1, V_1S_2 and V_6S_3 treatments.

4.1.1.3 Number of leaves per plant

Number of leaves per plant was recorded at an interval of 15 days starting from 30 DAS up to harvest. The mean values on number of leaves per plant and the results have been shown in Table 4.IIIa and 4.IIIb.

Variety

Number of leaves per plant was both significantly and non-significantly affected by different varieties (Table 4.IIIa). At the age of 30 DAS, the highest number of leaves per plant (12.81) was obtained from variety, V_5 which was significantly higher than V_2 (11.16) and V_6 (11.72). At 45 DAS, all varieties produced statistically identical number of leaves per plant although the maximum was noted from V_5. Variety, V_1 produced significantly maximum number of leaves per plant at the age of 60 DAS and was statistically at par to only V_5. At the age of 75 and 90 DAS, statistically alike number of leaves per plant were recorded from all varieties and ranged from 40.19-43.72 and 26.03-28.47 respectively. At harvest, the highest number of leaves per plant (17.78) was noted from V_1 which was statistically similar to V_6 (16.81) but significantly different from rest of the varieties. At this age V_2 produced minimum number of leaves per plant (13.59).

Sowing time

Sowing time had significant and non-significant responses on the number of leaves per plant in wheat (Table 4.IIIb). At all the ages number of leaves per plant were recorded maximum due to S_1 treatment and minimum number from S_4 treatment. At the age of 30 and 45 DAS, significantly higher number of leaves per plant noted from S_1 treatment were statistically identical to S_3 treatment. But from 60 DAS up to harvest, number of leaves per plant produced by S_1 treatment were significantly different from those of all other treatments. In all the varieties, maximum number of leaves were produced at the age of 60 DAS and thereafter, gradually decreased up to harvest.

Combined treatments

Both significant and non-significant variations among the treatments were observed due to combined treatments on the number of leaves per plant in wheat (Table 4.IIIb).

Table 4.IIIa. Effects of sowing time on number of leaves per plant of six varieties of wheat at different ages during 2014-2015 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Variety (V)						
V_1	12.25 ab	24.36 a	55.04 a	42.25 a	28.47 a	17.78 a
V_2	11.16 c	22.48 a	44.97 c	40.66 a	26.03 a	13.59 c
V_3	11.81 a-c	22.81 a	45.38 c	40.19 a	27.16 a	15.59 bc
V_4	12.50 ab	22.88 a	47.50 bc	43.03 a	27.16 a	15.53 bc
V_5	12.81 a	24.59 a	51.16 ab	43.72 a	26.16 a	15.38 bc
V_6	11.72 bc	22.05 a	44.31 c	39.50 a	27.78 a	16.81 ab
Sowing time (S)						
S_1	13.81 a	27.97 a	55.04 a	50.56 a	33.60 a	20.06 a
S_2	11.04 b	20.60 b	45.75 b	40.19 b	27.25 b	16.38 b
S_3	13.25 a	26.44 a	47.40 b	39.71 b	25.69 b	14.27 c
S_4	10.06 b	17.77 b	39.08 c	35.77 b	21.96 b	12.42 c
CV (%)	10.81	15.87	16.01	14.02	7.92	15.72
LSD (0.05)	1.00	3.88	4.57	7.15	6.10	2.02

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.IIIb. Combined effects of variety and sowing time on number of leaves per plant of wheat at different ages during 2014-2015 season.

Treatments	Age of plants at days after sowing (DAS)					At harvest
	30	45	60	75	90	
(Variety × Sowing time)						
V_1S_1	11.50 e-g	26.19 b-d	51.00 d-f	43.75 a-c	35.75 ab	22.63 a
V_2S_1	10.63 gh	23.31 d-f	47.00 f-h	40.13 b-d	30.88 b-d	16.75 e-g
V_3S_1	16.13 a	31.44 a	60.00 b	48.13 a	38.50 a	23.13 a
V_4S_1	14.88 b	29.31 a-c	57.00 bc	46.69 ab	34.13 a-c	19.25 b-d
V_5S_1	16.25 a	31.00 a	64.63 a	46.50 ab	31.75 b-d	20.38 b
V_6S_1	13.50 c	26.56 b-d	50.63 d-f	39.75 b-d	30.63 b-e	18.25 c-e
V_1S_2	13.38 cd	23.50 de	49.75 ef	35.50 d-h	28.00 d-g	18.50 b-e
V_2S_2	13.00 cd	24.06 d	55.00 cd	39.75 b-d	29.38 c-f	15.25 gh
V_3S_2	10.38 hi	19.44 f-h	43.00 h-j	32.38 b-d	26.13 d-i	14.88 gh
V_4S_2	10.75 ef	19.38 gh	41.38 i-k	34.38 d-h	24.63 e-j	15.50 gh
V_5S_2	7.88 k	17.38 gh	43.50 hi	36.13 d-g	26.88 d-h	16.75 e-g
V_6S_2	10.88 f-h	19.88 e-g	41.88 i-k	36.63 c-f	28.50 c-g	17.38 d-f
V_1S_3	12.38 de	28.88 a-c	49.75 ef	36.88 c-e	26.88 d-h	16.25 fg
V_2S_3	11.75 ef	24.94 d	41.50 i-k	32.50 e-h	23.75 f-j	11.13 j
V_3S_3	11.38 e-h	23.44 de	40.75 i-l	29.50 f-h	22.50 g-j	10.75 j
V_4S_3	14.00 bc	25.50 cd	52.25 de	36.50 d-g	24.00 f-j	13.50 hi
V_5S_3	16.38 a	29.94 ab	51.50 d-f	35.25 d-g	26.00 d-j	14.13 h
V_6S_3	13.63 c	25.94 cd	48.63 e-g	40.00 b-d	31.00 b-d	19.88 bc
V_1S_4	11.75 ef	18.88 gh	39.88 j-m	34.25 d-g	23.25 g-j	13.75 hi
V_2S_4	9.25 j	17.63 gh	36.38 lm	30.50 e-h	23.25 g-j	11.25 j
V_3S_4	9.38 ij	16.94 gh	37.75 k-m	28.75 h	20.13 ij	13.63 hi
V_4S_4	10.38 hi	17.31 gh	39.38 j-m	33.44 d-g	21.50 h-j	13.88 h
V_5S_4	10.75 f-h	20.06 e-g	45.00 g-i	30.38 e-h	25.88 d-j	10.25 j
V_6S_4	8.88 jk	15.81 h	36.13 m	29.38 gh	20.00 j	11.75 ij
CV (%)	10.81	15.87	16.01	14.02	7.92	15.72
LSD (0.05)	1.00	3.88	4.57	7.15	6.10	2.02

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

At the age of 30 DAS, number of leaves per plant ranged from 7.88-16.25 where, V_5S_1 treatment produced significantly higher number of leaves than all treatments except V_3S_1. The maximum number of leaves per plant (31.44) at 45 DAS was recorded from V_3S_1 treatment although statistically similar to V_4S_1 (29.31), V_5S_1 (31.00), V_1S_3 (28.88) and V_5S_3 (29.94) but significantly different from rest of the treatments. At this stage V_6S_4 treatment resulted lowest number of leaves per plant (15.81). At 60 DAS, significantly maximum number of leaves per plant (64.63) was noted from V_5S_1 treatment whereas, the minimum (36.13) was from V_6S_4 treatment. At 75 and 90 DAS, V_3S_1 treatments produced significantly higher number of leaves per plant than all other treatments except V_1S_1 and V_4S_1 but at 75 DAS also V_5S_1. At harvest, the highest number of leaves per plant (23.13) was recorded from V_3S_1 followed by V_1S_1 (22.63) treatment and both of these treatments are statistically identical but significantly different from rest of the treatments. The lowest number of leaves per plant (10.25) was obtained from V_5S_4 treatment which was significantly not different from those of V_2S_1, V_3S_1 and V_6S_4.

4.1.1.4 Total dry matter per plant

Total dry matter (TDM) per plant was recorded at six different ages starting from 30 DAS up to harvest. The mean values of TDM per plant are presented in Table 4.IVa and 4.IVb.

Variety

Varieties had both significant and non-significant effects on TDM per plant of wheat (Table 4.IVa). At the age of 30 DAS, TDM obtained from different varieties ranged from 0.63-0.76 g where, the maximum was recorded from V_4 which was significantly higher than V_5 and V_6. The maximum TDM (2.21 g) at the age of 45 DAS was found from the V_3 and was statistically alike to other varieties except V_1. At 60 DAS, all the varieties produced statistically similar TDM where, the maximum value was noted from V_5. The highest TDM per plant (18.62 g) at 75 DAS was recorded from V_3 followed by V_2 (18.50 g) and V_4 (17.67 g) respectively and all these are statistically identical. At this age the lowest TDM was obtained from V_6 (15.10 g) and statistically similar to V_5 (15.14 g). At the age of 90 DAS and at harvest V_3 resulted maximum TDM per plant.

Table 4.IVa. Effects of sowing time on total dry matter (g) per plant of six varieties of wheat at different ages during 2014-2015 season.

Treatments	Age of plant at days after sowing (DAS)					At harvest
	30	45	60	75	90	
Variety (V)						
V_1	0.66 ab	1.87 b	3.86 a	16.56 b	19.54 b	29.42 a
V_2	0.70 ab	2.16 a	4.09 a	18.50 a	21.55 a	31.50 a
V_3	0.71 ab	2.21 a	4.12 a	18.62 a	21.90 a	31.82 a
V_4	0.76 a	1.96 ab	4.30 a	17.67 ab	20.18 b	29.96 a
V_5	0.63 b	2.07 ab	4.35 a	15.14 c	18.26 c	28.04 a
V_6	0.64 b	2.05 ab	3.99 a	15.10 c	17.99 c	28.05 a
Sowing time (S)						
S_1	0.77 a	2.61 a	4.65 a	18.43 a	21.12 a	34.29 a
S_2	0.66 bc	1.48 b	3.07 b	16.50 bc	20.55 a	29.01 b
S_3	0.74 ab	2.55 a	4.43 a	17.37 ab	20.14 a	28.85 b
S_4	0.57 c	1.57 b	4.33 a	15.42 c	17.79 b	27.04 b
CV (%)	11.24	9.61	11.89	16.43	12.44	6.89
LSD (0.05)	0.10	0.25	0.59	1.27	1.16	3.86

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.IVb. Combined effects of variety and sowing time on total dry matter (g) per plant of wheat at different ages during 2014-2015 season.

Treatments	Age of plants at days after sowing (DAS)					At harvest
	30	45	60	75	90	
(Variety × Sowing time)						
V_1S_1	0.76 a-c	2.06 e	3.96 de	15.79 fg	18.73 k-n	33.03 b-d
V_2S_1	0.78 ab	2.84 ab	4.78 bc	19.83 b	23.43 b	35.83 ab
V_3S_1	0.81 a	3.01 a	5.70 a	23.07 a	25.66 a	39.01 a
V_4S_1	0.80 a	2.36 d	4.21 c-e	18.67 bc	19.97 e-j	34.20 bc
V_5S_1	0.69 b-d	2.84 ab	4.84 b	18.47 c	20.08 e-i	32.97 b-e
V_6S_1	0.78 ab	2.54 cd	4.40 b-e	14.77 gh	18.86 j-n	30.70 c-g
V_1S_2	0.67 cd	1.11 h	2.57 f	14.13 hi	19.18 i-n	29.12 e-i
V_2S_2	0.77 a-c	1.63 fg	2.86 f	17.69 c-e	21.04 e-e	32.17 b-f
V_3S_2	0.79 ab	1.76 f	2.28 f	15.62 fg	21.82 c	30.75 c-g
V_4S_2	0.78 ab	1.57 f-h	4.20 de	17.75 c-e	21.07 c-e	29.35 d-i
V_5S_2	0.54 fg	1.35 h	3.83 e	17.09 de	20.41 d-h	26.68 h-j
V_6S_2	0.41 h	1.46 gh	2.69 f	16.72 ef	19.80 f-k	25.98 ij
V_1S_3	0.65 de	2.52 cd	4.47 b-d	18.35 cd	20.94 c-f	27.69 g-i
V_2S_3	0.77 a-c	2.44 cd	4.46 b-d	18.08 cd	21.34 cd	29.91 d-h
V_3S_3	0.78 ab	2.59 b-d	4.40 b-e	18.26 cd	20.60 d-g	29.15 e-i
V_4S_3	0.80 a	2.52 cd	4.41 b-e	18.52 c	21.49 cd	28.29 g-i
V_5S_3	0.72 a-d	2.64 bc	4.37 b-e	12.93 ij	18.14 n	25.78 ij
V_6S_3	0.74 a-d	2.59 b-d	4.46 b-d	18.10 cd	18.36 ln	32.25 b-e
V_1S_4	0.55 e-g	1.77 f	4.44 b-d	17.97 c-e	19.32 h-m	27.83 g-i
V_2S_4	0.49 gh	1.75 f	4.27 b-e	18.40 c	20.40 d-h	28.07 g-i
V_3S_4	0.48 gh	1.46 gh	4.11 de	17.54 c-e	19.50 g-l	28.35 f-i
V_4S_4	0.67 cd	1.38 gh	4.37 b-e	15.74 fg	18.18 mn	28.01 g-i
V_5S_4	0.56 e-g	1.45 gh	4.36 b-e	12.07 jk	14.39 o	26.74 h-j
V_6S_4	0.64 d-f	1.63 fg	4.41 b-e	10.81 k	14.95 o	23.27 j
CV (%)	11.24	9.61	11.89	16.43	12.44	6.89
LSD (0.05)	0.10	0.25	0.59	1.27	1.16	3.86

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

The TDM obtained from V_3 at 90 DAS was significantly higher than all treatments except V_2 whereas, at harvest it was statistically identical to each other.

Sowing time

Both significant and non-significant variations among the treatment due to sowing times were observed on TDM per plant of wheat. Results indicated that S_1 treatment had resulted higher TDM than other treatments throughout the growing periods (Table 4.IVa). At 30 and 45 DAS, the maximum TDM per plant produced by S_1 treatment were significantly higher than other treatments except S_3. The TDM obtained at 60 DAS, ranged from 3.07-4.65 g where, significantly lowest value was observed from S_2 treatment. At 75 DAS, TDM per plant recorded from S_1 treatment (18.43 g) was significantly higher than S_2 (16.50 g) and S_4 (15.42 g) treatments. At 90 DAS, TDM per plant obtained from S_1 treatment although statistically at par to S_2 and S_3 treatments but significantly higher than S_4 treatment. At harvest, significantly maximum TDM per plant (34.29 g) was also obtained from S_1 treatment and followed by S_2 (29.01 g), S_3 (28.85 g) and S_4 (27.04 g) respectively.

Combined treatments

Combined treatments had both significant and non-significant influences on TDM per plant of wheat where, V_3S_1 treatment produced maximum value all over the growth periods (Table 4.IVb). The TDM obtained from V_3S_1 treatment at the age of 30 DAS were significantly higher than V_5S_1, V_1S_2, V_5S_2, V_6S_2, V_1S_3, V_1S_4, V_2S_4, V_3S_4, V_4S_4, V_5S_4 and V_6S_4 treatments where, V_6S_2 resulted the lowest value. At 45 DAS, TDM obtained from various treatments ranged from 1.11-3.01 g where, V_3S_1 treatment had significantly higher TDM than all other treatments except V_2S_1 and V_5S_1. At 60 DAS, significantly maximum TDM per plant (5.70 g) was recorded from V_3S_1 treatment followed by V_5S_1 (4.84 g), V_2S_1 (4.78 g) and V_1S_3 (4.47 g) treatments respectively. TDM per plant obtained from V_3S_1 treatment at the age of 75 and 90 DAS was also significantly different from all other treatments. At harvest, V_3S_1 treatment had significantly higher TDM per plant (39.01 g) than all other treatments except V_2S_1. The minimum value (23.27 g) was found from V_6S_4 treatment.

4.1.2 Effects of sowing time on yield attributes and yield

Data on yield contributing characters and yield were collected after harvest. The mean values of all parameters are presented in Table 4.Va and 4.Vb.

4.1.2.1 Number of effective tillers (spikes) per plant

Variety

Number of effective tillers per plant was both significantly and non-significantly affected by different varieties (Table 4.Va). The maximum number of effective tillers per plant (6.59) was recorded from V_1 followed by V_6 (6.38), V_3 (6.19) and V_5 (6.09) respectively. In this case, V_1 produced significantly higher number of effective tillers per plant than V_2 (5.25) and V_4 (5.88) treatments.

Sowing time

Sowing time had significant influences on the number of effective tillers per plant in wheat. Findings indicated in Table 4.Va revealed that number of effective tillers per plant significantly decreased with delayed sown wheat and the highest number was obtained from S_1 treatment (7.46) whereas, the lowest was from S_4 (4.52).

Combined treatments

Number of effective tillers per plant were significantly responded by various treatments and varied from 3.88-8.13 (Table 4.Vb). The highest number of effective tillers per plant was obtained from V_3S_1 treatment which was significantly higher than all other treatments except two treatments (V_1S_1 and V_5S_1). The minimum number of effective tillers per plant was observed from V_5S_4 treatment which was statistically identical to those of V_2S_3, V_2S_4 and V_6S_4 treatments.

4.1.2.2 Number of non-effective tillers per plant

Variety

Number of non-effective tillers per plant was non-significantly influenced by varietal effect where, the maximum (0.53) and minimum (0.19) number were noted from V_1 and V_3 respectively (Table 4.Va).

Table 4.Va. Effects of sowing time on yield attributes and yield of six varieties of wheat at harvest during 2014-2015 season.

Treatments	No. of effective tillers/ plant	No. of non-effective tillers/ plant	Length of spike (cm)	Dry weight of spikes (g)	No. of grains/ spike	No. of grains/ plant	1000-grain weight (g)	Yield/ plant (g)	Yield/ ha (t)	HI (%)
Variety (V)										
V_1	6.59 a	0.53 a	8.81 c	17.10 cd	24.06 c	158.73 a	45.08 b	7.44 c	3.72 c	25.39 ab
V_2	5.25 c	0.22 a	10.37 a	19.12 ab	32.08 a	165.62 a	48.91 a	8.38 ab	4.19 ab	26.48 a
V_3	6.19 ab	0.19 a	9.49 b	20.70 a	28.28 b	172.79 a	49.04 a	8.75 a	4.38 a	27.48 a
V_4	5.88 b	0.38 a	8.95 c	18.41 bc	28.53 b	168.12 a	42.18 d	7.39 c	3.69 c	24.76 ab
V_5	6.09 ab	0.22 a	9.01 bc	16.37 d	28.11 b	168.81 a	35.99 e	6.25 d	3.12 d	22.42 b
V_6	6.38 ab	0.38 a	7.87 d	16.87 d	26.06 bc	167.29 a	43.50 c	7.61 bc	3.81 bc	27.08 a
Sowing time (S)										
S_1	7.46 a	0.38 a	9.25 a	20.09 a	28.80 a	214.73 a	45.65 a	9.81 a	4.90 a	28.81 a
S_2	6.54 b	0.42 a	8.78 a	17.28 b	24.97 b	162.25 b	44.65 b	7.45 b	3.73 b	25.77 ab
S_3	5.73 c	0.21 a	9.16 a	17.62 b	28.29 a	159.07 b	43.71 c	7.25 b	3.63 b	25.42 ab
S_4	4.52 d	0.27 a	9.15 a	17.39 b	29.35 a	131.51 c	42.46 d	6.03 c	3.01 c	22.40 b
CV(%)	13.18	16.67	10.61	14.29	15.05	14.06	10.47	6.02	6.01	9.31
LSD(0.05)	0.59	0.47	0.51	1.69	2.59	20.23	0.20	0.90	0.43	3.90

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.Vb. Combined effects of variety and sowing time on yield attributes and yield of wheat at harvest during 2014-2015 season.

Treatments	No. of effective tillers/ plant	No. of non-effective tillers/ plant	Length of spike (cm)	Dry weight of spikes (g)	No. of grains/ spike	No. of grains/ plant	1000-grain weight (g)	Yield/ plant (g)	Yield/ ha (t)	HI (%)
Variety × Sowing time										
V_1S_1	7.63 a-c	0.63 ab	9.02 e-i	19.01 b-e	27.09 d-h	206.36 bc	46.28 f	9.67 b-d	4.83 b-d	29.41 a-c
V_2S_1	6.75 e-f	0.13 c	10.36 ab	20.48 b	29.94 bc	202.21 bc	50.19 b	10.23 b	5.12 b	28.69 a-d
V_3S_1	8.13 a	0.25 bc	10.00 bc	24.17 a	29.20 b-e	236.79 a	50.64 a	11.99 a	6.00 a	30.92 a
V_4S_1	7.38 cd	0.38 bc	8.87 f-i	20.38 b	30.06 b	221.50 ab	43.57 k	9.73 b-d	4.87 b-d	28.78 a-d
V_5S_1	8.00 ab	0.25 bc	9.12 d-g	18.51 c-g	28.63 b-f	229.27 a	37.64 q	8.49 e	4.24 e	25.93 c-h
V_6S_1	6.88 d-f	0.63 ab	8.14 jk	18.02 d-h	27.90 b-f	192.26 cd	45.60 g	8.75 e	4.37 e	29.14 a-c
V_1S_2	6.88 d-f	1.00 a	8.53 ij	15.92 i-k	21.34 k	146.25 g-k	45.36 h	6.85 f-h	3.43 f-h	24.07 e-i
V_2S_2	6.00 gh	0.25 bc	10.64 a	18.28 d-g	29.45 b-d	176.14 ef	49.43 c	8.91 de	4.46 de	27.71 a-e
V_3S_2	7.25 c-e	0.13 c	8.96 e-i	20.01 bc	24.96 g-i	180.35 de	49.31 c	9.13 c-e	4.57 c-e	29.91 ab
V_4S_2	5.88 h	0.50 bc	8.97 e-i	18.60 c-f	27.39 c-g	160.79 fg	42.69 l	7.07 fg	3.53 f	24.11 e-i
V_5S_2	6.50 fg	0.38 bc	8.65 g-j	15.01 k	24.50 h-j	159.38 f-h	36.54 r	5.90 i	2.95 i	22.40 g-i
V_6S_2	6.75 e-f	0.25 bc	6.92 l	15.82 i-k	22.20 jk	150.62 g-j	44.54 j	6.85 f-h	3.43 f-h	26.42 b-f
V_1S_3	6.63 f	0.25 bc	8.52 ij	16.36 h-k	22.84 i-k	151.39 g-i	45.08 i	7.09 f	3.55 f	26.17 b-g
V_2S_3	4.13 lm	0.25 bc	10.26 ab	19.18 b-d	35.29 a	145.38 g-k	48.75 d	7.36 f	3.68 f	24.54 e-i
V_3S_3	4.88 i-k	0.13 c	9.43 de	19.63 b-d	29.27 b-e	140.87 g-k	48.63 d	7.13 f	3.57 f	24.93 d-i
V_4S_3	5.25 i	0.25 bc	8.97 e-i	17.33 e-i	26.75 e-h	140.38 h-k	41.82 n	6.17 g-i	3.08 g-i	22.25 hi
V_5S_3	6.00 gh	0.00 c	9.19 d-f	15.05 k	26.50 f-h	159.13 f-h	35.53 s	5.89 i	2.94 i	23.42 f-i
V_6S_3	7.50 bc	0.38 bc	8.60 h-j	18.18 d-g	29.07 b-f	217.29 ab	42.45 m	9.88 bc	4.94 bc	31.23 a
V_1S_4	5.25 i	0.25 bc	9.16 d-g	17.13 f-j	24.97 g-i	130.91 jk	43.60 k	6.13 hi	3.07 hi	21.93 i
V_2S_4	4.13 lm	0.25 bc	10.23 ab	18.53 c-g	33.66 a	138.77 i-k	47.26 e	7.02 f-h	3.51 fg	24.99 d-i
V_3S_4	4.50 j-l	0.25 bc	9.59 cd	18.98 b-e	29.69 bc	133.15 i-k	47.60 d	6.74 f-i	3.37 e	24.15 e-i
V_4S_4	5.00 ij	0.38 bc	8.99 e-i	17.34 e-i	29.94 bc	149.81 g-j	40.62 p	6.58 f-i	3.29 f-i	23.89 e-i
V_5S_4	3.88 m	0.25 bc	9.10 d-h	16.89 g-j	32.79 a	127.45 kl	34.27 t	4.72 j	2.36 j	17.93 j
V_6S_4	4.38 k-m	0.25 bc	7.82 k	15.46 jk	25.06 g-i	109.00 l	41.39 o	4.96 j	2.48 j	21.53 ij
CV(%)	13.18	16.67	10.61	14.29	15.05	14.06	10.47	6.02	6.01	9.31
LSD(0.05)	0.59	0.47	0.51	1.69	2.59	20.23	0.20	0.90	0.43	3.90

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Sowing time

Sowing time had non-significant responses on the number of non-effective tillers per plant although the maximum value (0.42) was obtained from S_2 followed by S_1 (0.38) treatment and the minimum number of non-effective tillers per plant was observed from S_3 treatment (Table 4.Va).

Combined treatments

Results presented in Table 4.Vb indicated that sowing time had noteworthy influences on the number of non-effective tillers per plant in wheat. The V_1S_2 (1.00) treatment resulted significantly higher number of non-effective tillers per plant than all other treatments except V_1S_1 and V_6S_1. In this case the lowest value (0.00) was obtained from V_5S_3 treatment.

4.1.2.3 Length of spike

Variety

Length of spike was influenced both significantly and non-significantly by different varieties (Table 4.Va). Significantly longest spike (10.37 cm) was obtained from V_2 followed by V_3 (9.49 cm), V_5 (9.01 cm), V_4 (8.95 cm), V_1 (8.81 cm) and V_6 (7.87 cm) respectively.

Sowing time

Sowing time had non-significant response on length of spike (Table 4.Va). The longest spike (9.25 cm) was obtained from S_1 treatment and the shortest one (8.78 cm) was obtained from S_2 treatment.

Combined treatments

Both significant and non-significant responses have been observed in case of length of spike following different combined treatments (Table 4.Vb). The longest spike (10.64 cm) was found from V_2S_2 treatment although statistically similar to V_2S_1 (10.36 cm), V_2S_3 (10.26 cm) and V_2S_4 (10.23 cm) treatments but significantly different from rest of the treatments.

4.1.2.4 Dry weight of spike

Variety

The effect of different wheat varieties on the dry weight of spike was both significant and non-significant (Table 4.Va). Variety, V_3 produced highest dry weight of spike (20.70 g) which was significantly different from all other varieties except V_2 (19.12 g). The lowest dry weight of spike was found from V_5 (16.37 g).

Sowing time

Dry weight of spikes responded both significantly and non-significantly by sowing time (Table 4.Va). The amount recorded from S_1 treatment (20.09 g) was significantly higher than all other treatments, whereas, those recorded from S_2, S_3 and S_4 were statistically identical.

Combined treatments

Dry weight of spikes was remarkably affected by various combined treatments where, values ranged from 15.05-24.17 g, the maximum being due to V_3S_1 and the minimum due to V_5S_3 treatment (Table 4.Vb). Dry weight obtained from V_3S_1 treatment was significantly different from all other treatments, whereas, the minimum obtained from V_3S_3 treatment was statistically identical to V_1S_2, V_5S_2, V_6S_2, V_1S_3 and V_6S_4 treatments.

4.1.2.5 Number of grains per spike and plant

Variety

Number of grains per spike was both significantly and non-significantly influenced by different varieties of wheat where the highest was obtained from V_2 (32.08) and it was significantly different from all other treatments. The lowest number of grains per spike was obtained from V_1 which was also significantly different from those of all other treatments. Although the maximum number grains per plant (172.79) was recorded from V_3 but was statistically identical to rest of the treatments (Table 4.Va).

Sowing time

Number of grains per spike and number of grains per plant were both significantly and non-significantly influenced by sowing time (Table 4.Va). Number of grains per spike recorded varied from 24.97-29.35 where S_1, S_3 and S_4 treatments produced significantly higher values than S_2 treatment. However, in case of number of grains per plant, significantly maximum grains (214.73) was noted from S_1 followed by S_2 (162.25), S_3 (159.07) and S_4 (131.51) treatments respectively.

Combined treatments

Combined treatments had significant responses on the number of grains per spike and grains per plant (Table 4.Vb). Number of grains per spike (35.29) found from V_2S_3 treatments was significantly higher than all other treatments except V_2S_4 (33.66) and V_5S_4 (32.79) treatments. Significantly maximum number of grains (236.79) per plant was observed from V_3S_1 treatment which was statistically at par to V_4S_1 (221.50), V_5S_1 (229.27) and V_6S_3 (217.29) treatments. The minimum number of grains per spike was recorded from V_1S_2 which was statistically not different from those of V_6S_2 and V_1S_3 treatments whereas, the minimum number of grains per plant (109.00) was recorded from V_6S_4 treatment which was statistically identical to V_5S_4.

4.1.2.6 1000-grain weight

Variety

Variety had both significant and non-significant influences on 1000-grain weight of wheat (Table 4.Va). The 1000-grain weight was recorded maximum from V_3 (49.04 g) although statistically equal to V_2 (48.91 g) but significantly higher than rest of the treatments. Variety, V_4 had significantly lowest value in 1000-grain weight (35.99 g).

Sowing time

Findings presented in Table 4.Va indicated that sowing time had significant effect on 1000-grain weight. Weight of 1000-grain varied from 42.46-45.65 g where it was significantly decreased with delayed sowing.

Combined treatments

Significant responses has been observed in 1000-grain weight of wheat following various combined treatments and ranged from 34.27-50.64 g (Table 4.Vb). The 1000-grain weight (50.64 g) obtained from V_3S_1 treatment was significantly maximum and followed by V_2S_1 (50.19 g), V_2S_2 (49.43 g), V_3S_2 (49.31 g) treatments respectively. The lowest value (34.27 g) was found from V_5S_4 treatment which was also significantly different from rest of the treatments.

4.1.2.7 Yield per plant and per hectare

Variety

Yield per plant and per ha were both significantly and non-significantly influenced by different varieties of wheat (Table 4.Va). The maximum yield per plant (8.75 g) and yield per ha (4.38 t) were recorded from V_3 statistically identical to V_2 but significantly different from rest of the treatments. The lowest yield per plant (6.25 g) and yield per ha (3.12 t) were noted from V_5 and it was significantly different from all other treatments.

Sowing time

Sowing time had both significant and non-significant responses on yield per plant and yield per ha of wheat (Table 4.Va). The trend obtained in yield per plant and yield per ha was similar and decreased significantly with delayed sowing. Maximum yield per plant (9.81 g) and yield per ha (4.90 t) were recorded from S_1 treatment and were significantly different from rest of the treatments. Yield per plant and per ha due to S_2 and S_3 treatments were statistically identical to each other but different from those of S_1 and S_4 treatments. Whereas, significantly lowest yield per plant (6.03 g) and yield per ha (3.01 t) was obtained from S_4 treatment.

Combined treatments

Significant responses in yield per plant and per ha were observed from different treatments (Table 4.Vb). The maximum yield per plant (11.99 g) and yield per ha (6.00 t) were obtained from V_3S_1 treatment and were significantly higher than all other treatments but followed by V_2S_1, V_6S_3 and V_4S_1 treatments respectively in both cases.

The minimum yield per plant (4.72 g) and yield per ha (2.36 t) were obtained from V_5S_4 treatment and were significantly not different from those of V_6S_4 treatment.

4.1.2.8 Harvest index

Variety

Harvest index (HI) was both significantly and non-significantly influenced by different varieties of wheat and values obtained ranged from 22.42-27.48 % (Table 4.Va). The maximum HI was found from V_3 which was significantly different from V_5 where, the minimum value was noted.

Sowing time

Results revealed that HI decreased gradually with delayed sowing (Table 4.Va). The highest HI (28.81%) was obtained from S_1 treatment followed by S_2 (25.77%) and S_3 (25.42%) and were statistically not different from one another . The lowest HI was obtained from and S_4 (22.40%) and it was statistically identical to those of S_2 and S_3 treatments.

Combined treatments

Various combined treatments had both significant and non-significant effect on HI of wheat. The maximum HI (31.23%) was recorded from V_6S_3 treatment although statistically identical to V_1S_1 (29.41%), V_2S_1 (28.69%), V_3S_1 (30.92%), V_4S_1 (28.78%), V_6S_1 (29.14%), V_2S_2 (27.71%) and V_3S_2 (29.91%) but significantly higher than rest of the treatments (Table 4.Vb). However, the minimum HI (17.93%) was obtained from V_5S_4 treatment and statistically at par to only that of V_6S_4 treatment.

4.2 Experiment 2 carried out during the season of 2015-2016

Experiment 2 was carried out with seven concentrations of NAA as foliar spray in combination with five N-levels on BARI Gom-25 to find out better performing treatment. In this experiment in the texts, tables and figures SS_0, SS_1, SS_2, SS_3, SS_4, SS_5 and SS_6 represent control, foliar application of 10, 20, 30, 40, 50 and 60 ppm NAA respectively. Whereas, fertilizer treatments indicated here in as F_0, F_1, F_2, F_3 and F_4 represent 0, 25, 50, 75 and 100% of the recommended dose of N-fertilizer respectively. There were thirty five combination treatments and have been represented as SS_0F_0,

SS_1F_0, SS_2F_0, SS_3F_0, SS_4F_0, SS_5F_0, SS_6F_0, SS_0F_1,SS_1F_1, SS_2F_1, SS_3F_1, SS_4F_1, SS_5F_1, SS_6F_1 and so on.

4.2.1 Effects NAA and N-fertilizer on physiological parameters

4.2.1.1 Plant height

Plant height of BARI Gom-25 influenced by NAA alone and in combination with different N-levels was measured at six different ages starting from 30 DAS up to harvest and are presented in Table 4.VIa and Table 4.VIb.

NAA

Different concentrations of NAA had both significant and non-significant responses on plant height of BARI Gom-25 at different ages (Table 4.VIa). At the age of 30 and 45 DAS, the tallest plant was obtained from SS_6 treatment which was significantly higher than SS_0, SS_1 and SS_2 treatments. In both of these ages, SS_0 treatment produced significantly shortest plant (34.77 cm). Plant height obtained at the age of 60 DAS varied from 61.02-64.57 cm where, the tallest and the shortest plant were also noted from SS_6 and SS_0 treatments respectively but with non-significant variations. At 75 and 90 DAS, all concentrations of NAA produced statistically similar height. But at harvest, SS_5 treatment resulted the tallest plant (86.80 cm) whereas, SS_1 resulted the shortest plant (85.04 cm) and both were significantly different from each other. Here, the maximum increase due to SS_5 treatment was 0.60% compared to control.

N-fertilizer

Significant influences have been observed on height of BARI Gom-25 plant following different levels of N-fertilizer (Table 4.VIa). At 30 DAS, significantly taller plant (36.40 cm) was recorded from F_3 treatment which was statistically similar to F_2 and F_4 treatments. The shortest plant (34.07 cm) was obtained from F_0 treatment which was significantly lower than rest of the treatments. Higher rates of N-fertilizer significantly increased plant height at 45 DAS where, the maximum increase due F_4 treatment was 9.95% over the control followed by F_3 (8.12%), F_2 (5.89%) and F_1 (4.31%) treatments respectively. At the age of 60 DAS, plant height varied from 61.20-67.70 cm where, the longest plant was recorded from F_4 treatment..

Table 4.VIa. Effects of NAA and N-fertilizer on plant height of BARI Gom-25 at different ages during 2015-2016 season.

Treatments	Age of plants at days after sowing (DAS)					At harvest
	30	45	60	75	90	
NAA (SS)						
SS_0	34.77 d	47.98 c	61.02 a	83.58 a	86.21 a	86.28 ab
SS_1	35.41 c	48.86 b	63.64 a	83.87 a	85.59 a	85.04 b
SS_2	35.62 bc	48.99 b	63.53 a	83.72 a	85.59 a	86.18 ab
SS_3	35.91 ab	49.66 a	64.29 a	84.15 a	85.02 a	85.06 b
SS_4	36.07 a	49.88 a	64.03 a	84.13 a	86.48 a	86.62 ab
SS_5	36.00 a	49.68 a	63.82 a	85.21 a	86.44 a	86.80 a
SS_6	36.19 a	49.99 a	64.57 a	85.10 a	86.61 a	86.30 ab
Fertilizer (F)						
F_0	34.07 c	46.65 e	61.37 b	80.46 b	83.17 b	83.10 c
F_1	35.62 b	48.66 d	61.20 b	83.93 ab	86.01 ab	86.04 b
F_2	36.16 a	49.40 c	63.16 ab	83.52 ab	85.90 ab	85.94 b
F_3	36.40 a	50.44 b	65.26 ab	85.86 a	87.07 a	87.12 ab
F_4	36.29 a	51.29 a	67.70 a	86.77 a	87.84 a	88.44 a
CV (%)	3.66	4.31	9.93	6.20	5.49	3.60
LSD (0.05)	0.33	0.49	5.61	3.51	3.21	1.65

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.VIb. Combined effects of NAA and N-fertilizer on plant height of BARI Gom-25 at different ages during 2015-2016 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
(SS × F)	30	45	60	75	90	
SS_0F_0	30.71 w	42.53 u	56.34 h	76.38 j	80.88 jk	80.92 o
SS_1F_0	32.73 v	44.63 t	59.59 gh	79.00 h-j	81.13 i-k	81.18 o
SS_2F_0	33.68 u	45.44 s	59.93 f-h	78.67 ij	79.35 k	81.28 o
SS_3F_0	34.71 s	47.65 pq	62.84 c-g	80.28 g-i	82.28 g-j	82.31 o
SS_4F_0	35.24 qr	48.45 no	63.09 b-g	80.09 g-i	85.01 c-h	85.03 k-n
SS_5F_0	35.45 o-q	48.50 no	63.19 a-g	84.67 b-f	85.37 b-g	85.48 j-n
SS_6F_0	36.00 j-l	49.34 kl	64.58 a-g	84.73 b-f	85.43 b-g	85.53 j-n
SS_0F_1	34.33 t	46.54 r	61.70 d-h	83.16 d-g	85.43 b-g	85.46 j-n
SS_1F_1	34.91 rs	47.48 q	59.58 gh	82.29 f-h	84.30 e-i	84.34 mn
SS_2F_1	35.35 o-q	48.27 no	61.68 d-h	83.23 d-g	86.28 b-f	86.28 f-l
SS_3F_1	35.95 k-m	49.01 lm	61.91 d-h	84.69 b-f	85.85 b-f	85.88 i-m
SS_4F_1	36.16 h-k	49.83 h-k	61.02 e-h	84.33 b-f	86.69 b-f	86.74 d-j
SS_5F_1	36.10 i-l	49.34 kl	60.58 e-h	84.59 b-f	85.94 b-f	85.98 g-m
SS_6F_1	36.56 b-f	50.16 g-i	61.91 d-h	86.18 b-e	87.60 b-d	87.63 c-g
SS_0F_2	35.63 m-o	48.73 mn	61.56 e-h	83.03 e-g	87.34 b-e	87.35 c-i
SS_1F_2	36.85 ab	50.73 ef	65.73 a-e	85.79 b-f	88.17 bc	88.19 cd
SS_2F_2	36.58 b-e	49.69 i-k	63.01 b-g	84.75 b-f	87.78 b-d	87.83 c-f
SS_3F_2	36.66 a-d	50.66 ef	65.62 a-e	84.43 b-f	84.65 d-h	84.70 l-n
SS_4F_2	36.51 c-g	49.60 jk	64.04 a-g	83.86 c-f	87.03 b-f	87.08 c-j
SS_5F_2	35.41 o-q	48.13 p	60.67 e-h	82.44 f-h	84.19 f-i	84.20 n
SS_6F_2	35.52 n-q	48.28 no	61.49 e-h	80.33 g-i	82.13 h-k	82.25 o
SS_0F_3	36.23 f-k	50.14 g-i	63.08 b-g	84.33 b-f	85.97 b-f	86.05 g-l
SS_1F_3	36.38 d-i	50.34 fg	65.68 a-e	85.28 b-f	86.94 b-f	87.01 c-j
SS_2F_3	36.27 e-k	50.29 f-h	64.86 a-g	85.38 b-f	87.22 b-f	87.22 c-i
SS_3F_3	36.45 c-h	50.48 fg	65.68 a-e	85.96 b-e	86.45 b-f	86.47 e-k
SS_4F_3	36.13 h-k	50.01 g-j	63.77 a-g	85.43 b-f	86.25 b-f	86.26 f-l
SS_5F_3	36.57 b-e	50.77 d-f	66.13 a-e	87.04 bc	88.26 ab	88.32 cd
SS_6F_3	36.78 a-c	51.08 c-e	67.62 a-c	87.63 ab	88.43 a	88.49 bc
SS_0F_4	36.97 a	51.94 a	68.73 a	91.02 a	91.46 a	91.63 a
SS_1F_4	36.18 g-k	51.11 c-e	67.63 a-c	86.99 bc	87.39 b-f	87.63 c-g
SS_2F_4	36.23 f-k	51.26 b-d	68.14 a-c	86.56 b-d	87.31 b-f	88.28 cd
SS_3F_4	35.79 l-n	50.48 fg	65.38 a-c	85.41 b-f	85.87 b-f	85.94 h-m
SS_4F_4	36.33 d-j	51.48 a-c	68.25 a-c	86.91 bc	87.43 b-e	87.98 c-e
SS_5F_4	36.45 c-h	51.68 ab	68.53 ab	87.28 bc	88.43 a	90.04 ab
SS_6F_4	36.08 i-l	51.08 c-e	67.27 a-d	86.63 b-d	86.97 b-f	87.58 c-h
CV (%)	3.66	4.31	9.93	6.20	5.49	3.60
LSD (0.05)	0.33	0.49	5.61	3.51	3.21	1.65

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

The maximum plant height at the age of 75 and 90 DAS was found from F_4 treatment and were significantly taller than F_0 treatment but statistically at par with all other treatments in both ages. At harvest, the shortest (83.10 cm) and tallest (88.44 cm) plants were also recorded from F_0 and F_4 treatments respectively. At this stage, F_4 treatment produced significantly taller plant than all other treatments except F_3.

Combined treatments

Combined application of NAA and N-fertilizer had significant responses on height of BARI Gom-25 where, the tallest plant was found from SS_0F_4 treatment at all ages of growth (Table 4.VIb). Plant height following SSF_0 treatment was significantly different from all other treatment at 45 DAS but were statistically at par with some other treatments at other days. The shortest plant was recorded from SS_0F_0 treatment at all the ages except only at the age of 90 DAS. Increases in plant height following SS_0F_4 treatment were 20.38, 22.13, 21.99, 19.17, 13.08 and 13.24% at 30, 45, 60, 75, 90 DAS and at harvest respectively.

4.2.1.2 Number of tillers per plant

Number of tillers per plant was counted at an interval of 15 days from the age of 30 DAS up to harvest (Table 4.VIIa and 4.VIIb).

NAA

Foliar spray of NAA had mostly stimulating effects on the number of tillers per plant of BARI Gom-25 at different stages but with non-significant variations (Table 4.VIIa). At 30 DAS, number of tillers per plant obtained from different treatments varied from 1.95-2.20 where, the maximum was recorded from SS_6 treatment followed by SS_4 (2.13), SS_5 (2.12) and SS_3 (2.07) respectively. At 45 DAS, the highest number of tillers per plant was also noted from SS_6 treatment and was 4.55% higher over the control (SS_0). The maximum number of tillers per plant at the age of 60 DAS was obtained from SS_5 treatment followed by SS_6 and SS_4 treatments respectively. At 75 DAS, number of tillers per was recorded maximum (5.82) from SS_5 whereas, the minimum (5.58) was from SS_2 treatment. Treatments SS_3 and SS_5 produced maximum number of tillers per plant (4.03) at 90 DAS where the minimum number (3.83) was found from control.

Table 4.VIIa. Effects of NAA and N-fertilizer on the number of tillers per plant of BARI Gom-25 at different ages during 2015-2016 season.

Treatments	Age of plants at days after sowing (DAS)					At harvest
	30	45	60	75	90	
NAA (SS)						
SS_0	1.95 a	3.08 a	4.67 a	5.65 a	3.83 a	3.28 a
SS_1	1.95 a	2.63 a	4.57 a	5.62 a	3.97 a	3.35 a
SS_2	2.03 a	2.92 a	4.63 a	5.58 a	3.97 a	3.32 a
SS_3	2.07 a	3.03 a	4.67 a	5.67 a	4.03 a	3.37 a
SS_4	2.13 a	3.15 a	4.77 a	5.72 a	3.87 a	3.20 a
SS_5	2.12 a	3.10 a	4.80 a	5.82 a	4.03 a	3.30 a
SS_6	2.20 a	3.22 a	4.78 a	5.78 a	3.95 a	3.42 a
Fertilizer (F)						
F_0	1.31 c	2.23 b	3.95 b	4.93 c	3.27 c	2.75 b
F_1	2.04 b	3.02 a	4.64 a	5.64 b	4.07 ab	3.44 a
F_2	2.17 ab	3.02 a	4.75 a	5.75 b	3.81 b	3.14 ab
F_3	2.42 a	3.27 a	5.05 a	6.04 a	4.31 a	3.63 a
F_4	2.39 a	3.42 a	5.10 a	6.10 a	4.21 ab	3.57 a
CV (%)	9.86	9.30	16.39	14.46	6.98	14.15
LSD (0.05)	0.33	0.65	0.51	0.28	0.43	0.55

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.VIIb. Combined effects of NAA and N-fertilizer on the number of tillers per plant of BARI Gom-25 at different ages during 2015-2016 season.

Treatments (SS × F)	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
SS_0F_0	1.00 h	2.00 jk	3.58 j	4.50 o	3.17 jk	2.75 i-k
SS_1F_0	1.00 h	1.67 k	3.67 j	4.67 o	2.75 k	2.25 k
SS_2F_0	1.33 gh	2.25 i-k	3.83 ij	4.75 no	3.08 jk	2.42 jk
SS_3F_0	1.42 fg	2.33 h-j	4.00 h-j	5.00 mn	3.75 f-h	3.08 e-i
SS_4F_0	1.33 gh	2.25 i-k	4.00 h-j	5.00 mn	3.08 jk	2.42 jk
SS_5F_0	1.42 fg	2.42 g-j	4.25 g-i	5.25 lm	3.83 e-h	3.08 e-i
SS_6F_0	1.67 ef	2.67 e-i	4.33 f-i	5.33 kl	3.25 ij	3.25 c-i
SS_0F_1	1.50 fg	2.58 f-j	4.33 f-i	5.33kl	3.92 d-h	3.33 b-h
SS_1F_1	1.75 d-f	2.67 e-i	4.33 f-i	5.50 i-l	4.00 c-g	3.42 a-g
SS_2F_1	2.08 cd	3.00 b-g	4.67 c-g	5.67 g-j	4.08 b-g	3.50 a-f
SS_3F_1	2.25 bc	3.42 a-d	5.00 a-d	6.00 c-f	4.17 a-f	3.50 a-f
SS_4F_1	2.33 bc	3.33 a-d	4.75 b-g	5.58 h-k	4.08 b-g	3.42 a-g
SS_5F_1	2.33 bc	3.25 a-e	4.83 b-f	5.83 e-h	4.08 b-g	3.42 a-g
SS_6F_1	2.00 c-e	2.92 c-h	4.58 d-g	5.58 h-k	4.17 a-f	3.50 a-f
SS_0F_2	2.00 c-e	2.58 f-j	4.75 b-g	5.75 f-i	3.50 h-j	2.92 g-j
SS_1F_2	2.08 cd	2.83 d-i	4.58 d-g	5.58 h-k	3.67 g-i	3.08 e-i
SS_2F_2	2.17 bc	3.00 b-g	4.67 c-g	5.67 g-j	4.08 b-g	3.42 a-g
SS_3F_2	2.00 c-e	2.83 d-i	4.42 e-h	5.42 j-l	3.50 h-j	2.83 h-j
SS_4F_2	2.50 ab	3.58 ab	5.25 ab	6.25 a-c	3.92 d-h	3.25 c-i
SS_5F_2	2.17 bc	3.08 a-f	4.67 c-g	5.67 g-j	3.83 e-h	3.00 f-i
SS_6F_2	2.25 bc	3.25 a-e	4.92 a-e	5.92 d-g	4.17 a-f	3.50 a-f
SS_0F_3	2.50 ab	3.08 a-f	5.25 ab	6.25 a-c	4.25 a-e	3.58 a-e
SS_1F_3	2.42 ab	3.25 a-e	5.00 a-d	6.00 c-f	4.42 a-c	3.75 a-c
SS_2F_3	2.25 bc	3.08 a-f	5.08 a-d	5.92 d-g	4.00 c-g	3.33 b-h
SS_3F_3	2.33 bc	3.17 a-f	4.83 b-f	5.75 f-i	4.50 ab	3.83 ab
SS_4F_3	2.42 ab	3.50 a-c	5.08 a-d	6.08 b-e	4.33 a-d	3.67 a-d
SS_5F_3	2.33 bc	3.25 a-e	5.08 a-d	6.25 a-c	4.33 a-d	3.58 a-e
SS_6F_3	2.67 a	3.58 ab	5.00 a-d	6.00 c-f	4.33 a-d	3.67 a-d
SS_0F_4	2.75 a	3.42 a-d	5.42 a	6.42 a	4.33 a-d	3.83 ab
SS_1F_4	2.50 ab	3.58 ab	5.25 ab	6.33 ab	4.50 ab	3.83 ab
SS_2F_4	2.33 bc	3.25 a-e	4.92 a-e	5.92 d-g	4.58 a	3.92 a
SS_3F_4	2.33 bc	3.42 a-d	5.08 a-d	6.17 a-d	4.25 a-e	3.58 a-e
SS_4F_4	2.08 cd	3.08 a-f	4.75 b-g	5.67 h-j	3.92 d-h	3.25 c-i
SS_5F_4	2.33 bc	3.50 a-c	5.17 a-c	6.08 b-e	4.08 b-g	3.42 a-g
SS_6F_4	2.42 ab	3.67 a	5.08 a-d	6.08 b-e	3.83 e-h	3.17 d-i
CV (%)	9.86	9.30	16.39	14.46	6.98	14.15
LSD (0.05)	0.33	0.65	0.51	0.28	0.43	0.55

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

At harvest, SS_6 treatment resulted highest number of tillers per plant (3.42) followed by SS_3 (3.37), SS_1 (3.35), SS_2 (3.35), SS_0 (3.28) and SS_4 (3.20) treatments respectively.

N-fertilizer

Application of various N-levels had significant influences on the number of tillers per plant throughout the growth ages where, the minimum was obtained from F_0 treatment (Table 4.VIIa). At 30 DAS, significantly higher number of tillers per plant (2.42) was obtained from F_3 treatment although it was statistically similar to F_2 (2.17) and F_4 (2.39) treatments. At 45 DAS, different doses of N-fertilizer increased the number of tillers per plant where, the maximum increase was noted from F_4 and it was 53.36% higher over the control. Number of tillers per plant also increased at 60 and 75 DAS following different N-levels and the maximum increase was observed from F_4 treatment. At 90 DAS, the maximum increase in number of tillers per plant was observed from F_3 treatment followed by F_4, F_1 and F_2 treatments respectively. At harvest, number of tillers per plant increased by 25.09, 14.18, 32.00, 29.82% following F_1, F_2, F_3 and F_4 treatments respectively.

Combined treatments

Findings presented in Table 4.VIIb revealed that the number of tillers per plant was significantly influenced by combined application of NAA and various N-levels. Number of tillers per plant recorded at 30 DAS varied from 1.00-2.75 where the maximum number of tillers per plant was obtained from SS_0F_4 treatment which was significantly higher than all other treatments except SS_4F_2, SS_0F_3, SS_1F_3, SS_4F_3, SS_6F_3, SS_1F_4 and SS_6F_4. Foliar application of NAA in combination with varying N-levels had stimulatory effects on the number of tillers per plant at 45 DAS but with an exception of SS_1F_0 treatment. At this stage, the maximum increase was observed from SS_6F_4 treatment and it was 83.50% higher over the control. Number of tillers per plant augmented due to all treatments where, the maximum increase due to SS_0F_4 treatment was 51.40 and 42.67 % at the age of 60 and 75 DAS respectively. At 90 DAS, number of tillers per plant increased following all combined treatments except SS_1F_0, SS_2F_0 and SS_4F_0 treatments and the maximum increase was noted from SS_2F_4 treatment (44.48% higher over the control). Similar trends of increase in number of tillers per plant following different combined treatments was also observed at harvest. Both at 90 DAS and at harvest, the lowest number of tillers per plant was obtained from SS_1F_0 treatment although significantly not different from that of control (SS_0F_0).

4.2.1.3 Number of leaves per plant

Number of leaves per plant was recorded at an interval of 15 DAS from the age of 30 DAS up to harvest (Table 4.VIIIa and 4.VIIIb).

NAA

Results presented in Table 4.VIIIa showed that different concentrations of NAA produced higher number of leaves per plant up to the age of 75 DAS but with non-significant variations in all the days except at 30 DAS. At this period (30-75 DAS) the lowest and highest number of leaves per plant were obtained from SS_0 and SS_6 treatments respectively. However, at the age of 90 DAS and at harvest number of leaves per plant was recorded maximum from control treatment which was statistically identical to all other treatments.

N-fertilizer

Number of leaves per plant was significantly influenced by various doses of N-fertilizer throughout the growth periods (Table 4.VIIIa). At 30 DAS, different levels of N-fertilizer produced significantly higher number of leaves per plant where the maximum (9.54) was noted from F_3 treatment followed by F_4 (9.50), F_2 (8.79) and F_1 (8.58) respectively. From 45 DAS up to the age of 75 DAS application of all levels of N-fertilizers resulted maximum number of leaves from F_4 treatment although statistically identical to F_3 treatment. The maximum number of leaves per plant obtained from F_3 treatment at the age of 90 DAS and at harvest and the increases were 28.05 and 28.20% higher over the control respectively.

Combined treatments

Foliar application of NAA in combination with various N-levels had significant influences on the number of leaves per plant of BARI Gom-25 all over the growing periods (Table 4.VIIIb).

Table 4.VIIIa. Effects of NAA and N-fertilizer on the number of leaves per plant of BARI Gom-25 at different ages during 2015-2016 season.

Treatments	Age of plants at days after sowing (DAS)					At harvest
	30	45	60	75	90	
NAA (SS)						
SS_0	7.67 b	13.10 a	21.27 a	25.50 a	10.83 a	8.92 a
SS_1	8.12 ab	14.10 a	22.35 a	26.31 a	9.88 a	7.97 a
SS_2	8.20 ab	14.23 a	22.70 a	26.40 a	10.20 a	8.53 a
SS_3	8.42 ab	14.05 a	21.70 a	25.78 a	10.22 a	8.37 a
SS_4	8.48 ab	14.98 a	21.95 a	25.85 a	9.85 a	8.07 a
SS_5	8.52 ab	14.58 a	22.28 a	26.30 a	10.35 a	8.38 a
SS_6	8.80 a	15.28 a	22.46 a	26.55 a	10.03 a	8.45 a
Fertilizer (F)						
F_0	5.17 b	10.52 c	17.38 d	21.26 d	8.70 c	7.27 b
F_1	8.58 a	13.92 b	21.35 c	25.49 c	10.52 ab	8.48 ab
F_2	8.79 a	14.33 b	22.27 bc	26.36 bc	9.81 bc	7.88 ab
F_3	9.54 a	15.98 ab	24.53 ab	28.35 ab	11.14 a	9.32 a
F_0	9.50 a	16.92 a	24.98 a	29.04 a	10.80 ab	8.96 a
CV (%)	7.15	6.44	8.58	16.27	8.49	6.07
LSD (0.05)	1.12	2.41	2.29	2.49	1.23	1.59

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4VIIIb. Combined effects of NAA and N-fertilizer on the number of leaves per plant of BARI Gom-25 at different ages during 2015-2016 season.

Treatments (SS × F)	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
SS_0F_0	3.83 j	10.33 mn	14.83 s	19.67 p	8.92 j-l	7.08 i-m
SS_1F_0	4.00 j	8.83 n	15.42 rs	19.25 p	7.50 m	6.42 m
SS_2F_0	3.92 j	10.33 mn	17.42 qr	20.58 op	8.00 lm	6.92 k-m
SS_3F_0	5.92 i	10.50 l-n	18.00 o-q	22.25 m-o	9.92 e-j	8.08 c-l
SS_4F_0	5.50 i	10.75 k-n	17.58 p-r	21.58 n-p	7.92 lm	6.50 lm
SS_5F_0	5.83 i	10.58 l-n	18.50 n-q	22.50 l-o	10.17 d-i	7.92 d-m
SS_6F_0	7.17 h	12.33 j-m	19.92 l-o	23.00 k-o	8.50 k-m	8.00 d-m
SS_0F_1	6.58 hi	12.50 j-m	20.67 j-n	24.67 h-m	10.50 b-h	8.75 b-h
SS_1F_1	7.67 gh	13.42 h-m	21.83 h-m	26.50 d-i	9.58 g-k	6.83 k-m
SS_2F_1	9.00 b-f	13.83 g-l	23.75 c-h	27.92 b-f	10.75 b-g	9.00 b-g
SS_3F_1	9.17 a-f	15.00 d-i	21.92 g-m	26.08 e-i	10.75 b-g	8.75 b-g
SS_4F_1	9.58 a-e	15.00 d-i	19.75 m-p	23.33 j-n	10.67 b-g	8.67 c-i
SS_5F_1	9.50 a-e	14.00 g-k	20.33 k-n	24.75 g-l	10.50 b-h	8.58 c-j
SS_6F_1	8.58 e-g	13.67 g-m	21.17 i-m	25.17 g-k	10.92 b-f	8.75 b-h
SS_0F_2	8.33 fg	12.08 j-m	22.08 f-l	26.42 d-i	9.75 f-j	7.25 h-m
SS_1F_2	8.83 d-f	14.42 e-j	23.17 d-i	27.17 c-g	9.25 i-k	7.42 g-m
SS_2F_2	8.92 c-f	15.33 c-i	23.75 c-h	27.92 b-f	10.58 b-g	8.83 b-h
SS_3F_2	8.33 fg	13.17 i-m	20.17 l-o	24.17 i-m	8.83 j-l	7.00 j-m
SS_4F_2	9.33 a-f	16.75 a-e	24.50 a-e	28.42 a-e	9.83 e-j	7.92 d-m
SS_5F_2	8.83 d-f	14.17 f-j	22.50 e-k	24.92 g-l	9.75 f-j	7.83 e-m
SS_6F_2	8.92 c-f	14.42 e-j	21.42 i-m	25.50 f-j	10.67 b-g	8.92 b-g
SS_0F_3	9.50 a-e	13.67 g-m	22.67 e-j	26.67 d-h	11.92 ab	10.25 ab
SS_1F_3	9.83 a-d	16.00 b-g	24.65 a-e	28.46 a-e	11.67 b	9.67 bc
SS_2F_3	9.58 a-e	15.00 d-i	23.92 b-h	27.00 c-h	10.33 c-i	8.42 c-k
SS_3F_3	9.25 a-f	15.08 d-i	24.08 b-h	28.00 b-e	11.17 b-d	9.42 b-e
SS_4F_3	9.42 a-f	16.75 a-e	24.17 b-g	28.17 b-e	11.00 b-e	9.17 b-f
SS_5F_3	9.17 a-f	16.92 a-d	26.67 a	30.75 a	11.17 b-d	9.33 b-e
SS_6F_3	10.00 a-c	18.42 a	25.56 a-c	29.39 a-c	10.75 b-g	9.00 b-g
SS_0F_4	10.08 ab	16.92 a-d	26.08 ab	30.08 ab	13.08 a	11.25 a
SS_1F_4	10.25 a	17.83 ab	26.67 a	30.17 ab	11.42 bc	9.50 b-d
SS_2F_4	9.58 a-e	16.67 a-e	24.67 a-e	28.58 a-d	11.33 b-d	9.50 b-d
SS_3F_4	9.42 a-f	16.50 a-f	24.33 b-f	28.42 a-e	10.42 c-i	8.58 c-j
SS_4F_4	8.58 e-g	15.67 b-h	23.75 c-h	27.75 b-f	9.83 e-j	8.08 c-l
SS_5F_4	9.25 a-f	17.25 a-d	25.08 a-d	28.58 a-d	10.17 d-i	8.25 c-k
SS_6F_4	9.33 a-f	17.58 a-c	24.25 b-f	29.67 ab	9.33 h-k	7.58 f-m
CV (%)	7.15	6.44	8.58	16.27	8.49	6.07
LSD (0.05)	1.12	2.41	2.29	2.49	1.23	1.59

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

At the age of 30 DAS, number of leaves per plant varied from 3.83-10.25 where, the maximum was noted from SS_1F_4 treatment which was significantly higher than most of the treatments. The minimum number of leaves per plant was recorded from SS_0F_0 and it was statistically identical to SS_1F_0 and SS_2F_0 treatments. At 45 DAS the highest number of leaves per plant at 45 DAS was recorded from SS_6F_3 treatment and was significantly higher number of leaves than all other treatments except SS_4F_2, SS_4F_3, SS_5F_3, SS_0F_4, SS_1F_4, SS_2F_4, SS_3F_4, SS_5F_4 and SS_6F_4 treatments. The maximum increase recorded was 78.32% and the only decrease recorded was 14.52% due to SS_1F_0. At the age of 60 DAS the maximum increase was recorded from both SS_5F_3 and SS_1F_4 treatments and the range of increases varied from 3.98-79.84%. At 75 DAS, although the minimum (19.25) number of leaves per plants was noted from SS_1F_0 treatment but statistically not different from control (SS_0F_0). The maximum increase (56.33%) in number of leaves per plant at this stage was observed from SS_5F_3 treatment followed by SS_1F_4 (53.38%), SS_0F_4 (52.92%) and SS_6F_3 (49.41%) treatments respectively. Significantly maximum number of leaves per plant at 90 DAS (13.08) and at harvest (11.25) was observed from SS_0F_4 treatment but only statistically at par with SS_0F_3 treatment. At both of this ages, SS_1F_0 treatment had minimum number of leaves.

4.2.1.4 Total dry matter per plant

Total dry matter per plant was recorded from the age of 30 DAS up to harvest (Table 4.IXa and 4.IXb).

NAA

Significant and non-significant variations in total dry matter per plant were observed due to application of different concentrations of NAA treatments at all the ages. Maximum dry matter was produced by SS_2 treatment and was significantly different from control up to the age of 75 DAS (Table 4.IXa). At 30 DAS, dry matter per plant increased by 4.26-21.28%. At the age of 45 and 60 DAS the maximum increase in dry matter per plant was noted from SS_2 treatment followed by SS_5 and SS_6 treatments respectively. At 75 DAS, dry matter per plant varied from 7.29-8.68 g and the increases over control varied from 3.98 to 19.07%. In both 90 DAS and at harvest dry matter per plant following all the treatments were statistically identical.

Table 4.IXa. Effects of NAA and N-fertilizer on total dry matter (g) per plant of BARI Gom-25 at different ages during 2015-2016 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
NAA (SS)						
SS_0	0.94 d	2.58 d	5.98 d	7.29 c	9.29 a	10.69 a
SS_1	1.03 a-d	2.82 b-d	6.45 b-d	7.83 a-c	9.82 a	11.24 a
SS_2	1.14 a	3.13 a	7.22 a	8.68 a	10.55 a	12.13 a
SS_3	0.98 cd	2.68 cd	6.20 cd	7.58 bc	9.41 a	10.81 a
SS_4	1.00 b-d	2.74 cd	6.32 cd	7.66 bc	9.46 a	10.91 a
SS_5	1.11 ab	3.03 ab	7.01 ab	8.33 ab	10.13 a	11.38 a
SS_6	1.07 a-c	2.93 a-c	6.78 a-c	8.10 a-c	9.90 a	11.34 a
Fertilizer (F)						
F_0	0.66 c	1.81 c	4.18 c	5.51 c	7.30 b	8.67 b
F_1	1.17 a	3.20 a	7.40 a	8.72 a	10.57 a	12.03 a
F_2	0.85 b	2.32 b	5.36 b	6.73 b	8.48 b	9.81 b
F_3	1.26 a	3.44 a	7.96 a	9.29 a	11.07 a	12.57 a
F_4	1.26 a	3.46 a	7.93 a	9.37 a	11.56 a	12.99 a
CV (%)	13.54	9.32	12.91	8.08	7.01	13.65
LSD (0.05)	0.11	0.27	0.61	0.86	1.31	2.31

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.IXb. Combined effects of NAA and N-fertilizer on total dry matter (g) per plant of BARI Gom-25 at different ages during 2015-2016 season.

Treatments (SS × F)	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
SS_0F_0	0.32 n	0.90 k	2.09 l	3.34 n	5.09 q	6.43 q
SS_1F_0	0.47 m	1.28 j	2.97 k	4.22 m	5.89 pq	7.22 pq
SS_2F_0	0.49 m	1.32 j	3.05 k	4.30 m	6.05 pq	7.63 o-q
SS_3F_0	0.69 l	1.90 i	4.39 j	5.98 l	7.73 no	9.06 l-p
SS_4F_0	0.52 m	1.42 j	3.28 k	4.62 m	6.45 op	7.78 n-q
SS_5F_0	1.06 g-i	2.91 ef	6.75 e-g	8.08 f-i	10.00 f-i	11.33 d-l
SS_6F_0	1.07 g-i	2.91 ef	6.71 e-g	8.05 f-i	9.88 f-j	11.21 e-l
SS_0F_1	0.99 ij	2.69 fg	6.22 gh	7.55 ij	9.39 h-m	10.72 g-l
SS_1F_1	1.05 hi	2.87 ef	6.62 fg	7.79 hi	9.71 g-j	11.04 e-l
SS_2F_1	1.40 ab	3.84 b	8.89 ab	10.39 ab	12.23 bc	14.06 a-c
SS_3F_1	1.11 f-h	3.05 de	7.07 d-f	8.41 e-i	10.24 f-h	11.57 d-k
SS_4F_1	1.05 hi	2.89 ef	6.68 e-g	8.01 g-i	9.84 g-j	11.51 d-k
SS_5F_1	1.20 d-f	3.28 cd	7.58 cd	8.83 d-g	10.66 d-h	11.99 c-j
SS_6F_1	1.38 b	3.79 b	8.76 b	10.09 bc	11.93 cd	13.34 a-e
SS_0F_2	0.80 kl	2.21 h	5.10 i	6.43 kl	8.10 mn	9.43 k-p
SS_1F_2	0.98 ij	2.68 fg	6.21 gh	7.79 hi	9.62 h-l	10.96 f-l
SS_2F_2	1.06 g-i	2.91 ef	6.72 e-g	8.05 f-i	9.64 h-k	11.05 e-l
SS_3F_2	0.54 m	1.48 j	3.42 k	4.76 m	6.67 op	8.09 m-q
SS_4F_2	0.84 k	2.29 h	5.28 i	6.62 kl	8.37 k-n	9.70 j-o
SS_5F_2	0.83 k	2.27 h	5.23 i	6.56 kl	8.31 l-n	9.48 k-p
SS_6F_2	0.88 jk	2.39 h	5.53 i	6.87 jk	8.62 j-n	9.95 i-n
SS_0F_3	1.17 d-g	3.20 cd	7.41cd	8.74 d-g	10.57 e-h	12.07 c-i
SS_1F_3	1.20 d-f	3.27 cd	7.55 cd	8.88 d-f	10.47 f-h	11.97 c-j
SS_2F_3	1.26 cd	3.45 c	7.99 c	9.33 cd	11.16 c-f	12.74 b-g
SS_3F_3	1.36 bc	3.73 b	8.61 b	9.95 bc	11.78 c-e	13.20 a-f
SS_4F_3	1.42 ab	3.88 ab	8.97 ab	10.30 b	12.13 bc	13.55 a-d
SS_5F_3	1.25 c-e	3.42 c	7.92 c	9.25 c-e	11.00 c-g	12.42 c-h
SS_6F_3	1.14 e-h	3.14 de	7.28 de	8.61 d-h	10.36 f-h	12.03 c-i
SS_0F_4	1.42 ab	3.92 ab	9.07 ab	10.40 b	13.32 ab	14.82 ab
SS_1F_4	1.43 ab	3.98 ab	8.90 ab	10.49 ab	13.40 ab	15.02 ab
SS_2F_4	1.51 a	4.13 a	9.42 a	11.34 a	13.67 a	15.13 a
SS_3F_4	1.19 d-f	3.24 cd	7.49 cd	8.82 d-g	10.65 d-h	12.15 c-i
SS_4F_4	1.17 d-g	3.21 cd	7.41 cd	8.75 d-g	10.50 e-h	12.00 c-j
SS_5F_4	1.20 d-f	3.28 cd	7.58 cd	8.91 d-f	10.66 d-h	11.66 d-k
SS_6F_4	0.89 jk	2.44 gh	5.64 hi	6.89 jk	8.73 i-n	10.14 h-m
CV (%)	13.54	9.32	12.91	8.08	7.01	13.65
LSD (0.05)	0.11	0.27	0.61	0.86	1.31	2.31

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

The total dry matter per plant due to SS_2 treatments increased by 13.56 and 13.47% at 90 DAS and at harvest respectively.

N-fertilizer

Application of various N-levels produced significantly higher dry matter per plant of BARI Gom-25 throughout the growth periods except F_2 treatment of 90 DAS and at harvest (Table 4.IXa). At 30 DAS, dry matter per plant increased by 28.79-90.91% due to different treatments. The maximum increase due to F_4 treatment was 91.16, 89.71 and 70.05% at 45, 60 and 75 DAS respectively. At 90 DAS, total dry matter per plant increased by 44.79, 16.16, 51.64 and 58.36% due to F_1, F_2, F_3 and F_4 treatments respectively. At harvest, dry matter per plant varied from 8.67-12.99 g. At this age the maximum increase (49.83%) was also noted from F_4 treatment followed by F_3 (44.98%) and F_1 (38.75%) respectively.

Combined treatments

Foliar spray of NAA at varying N-levels had both significant and non-significant responses on the total dry matter per plant at different ages where, the minimum and maximum were obtained from SS_0F_0 (control) and SS_2F_4 treatments respectively (Table 4.IXb). Total dry matter per plant obtained from different combined treatment recorded from 30-75 DAS were significantly higher than control (SS_0F_0) and the maximum increase due to SS_2F_4 treatment was 371.86, 358.89, 350.72 and 240.52% at 30, 45, 60 and 75 DAS respectively. At the age of 90 DAS, all combined treatments produced significantly higher dry matter than control except SS_1F_0 and SS_2F_0 treatments. Total dry matter per plant increased by 12.29-139.97% at harvest. At harvest, SS_2F_4 treatment produced significantly maximum dry matter than all other treatments but with few exceptions (SS_2F_1, SS_6F_1, SS_3F_3, SS_4F_3, SS_0F_4 and SS_1F_4). The range of increases in total dry matter per plant varied from 12.29 to 135.30%.

4.2.2 Effects of NAA and N-fertilizer on yield attributes and yield

Data on yield attributes and yield were collected after harvest. The mean values of all parameters are presented in Table 4.Xa and 4.Xb.

4.2.2.1 Number of effective tillers (spikes) per plant

NAA

Number of effective tillers per plant was positively influenced by NAA treatments except SS_4 but with non-significant variations (Table 4.Xa). The maximum number of effective tillers per plant (3.27) was obtained from SS_2 treatment and it was 4.81% higher over the control. The minimum number of effective tillers per plant (3.05) was obtained from SS_4 treatment where it was decreased by 2.30% (Fig. 4.1a).

N-fertilizer

Different levels of N-fertilizer had significantly stimulatory effects on the number of effective tillers per plant of BARI Gom-25 (Table 4.Xa). Maximum number of effective tillers per plant were noted from F_3 and F_4 treatments but were statistically identical to F_1 and F_2 treatments. The increases due to both F_3 and F_4 treatments was 32.57% (Fig. 4.1b).

Combined treatments

Results presented in Table 4.Xb revealed that combined application of NAA and N-fertilizer had both positive and negative influences on the number of effective tillers per plant. Significantly higher number of effective tillers per plant were recorded from SS_1F_1, SS_2F_1, SS_5F_1, SS_6F_1, SS_2F_2, SS_4F_2, SS_6F_2, SS_0F_3, SS_1F_3, SS_2F_3, SS_3F_3, SS_4F_3, SS_5F_3, SS_6F_3, SS_0F_4, SS_1F_4, SS_2F_4, SS_3F_4, SS_4F_4 and SS_5F_4 treatments where, the maximum increase was 43.46% due to SS_2F_4 treatment followed by SS_1F_4 (40.50%). The maximum decrease was observed from SS_4F_0 treatment and it was 18.73% lower than the control ((Fig. 4.1c).

4.2.2.2 Number of non-effective tillers per plant

NAA

Results presented in Table 4.Xa showed that foliar application of NAA treatments mostly reduced the number of non-effective tillers per plant but with non-significant variation. In this case, SS_3 and SS_6 treatments produced similar number of non-effective tillers per plant (0.17) to control however, the lowest (0.05) was found from SS_2 treatment.

Table 4.Xa. Effects of NAA and N-fertilizer on yield attributes and yield of BARI Gom-25 at harvest during 2015-2016 season.

Treatments	No. of effective tillers/ plant	No. of non-effective tillers /plant	Length of spike (cm)	Dry weight of spikes (g)	No. of grains/ spike	No. of grains/ plant	1000-grain weight (g)	Yield /plant (g)	Yield /ha (t)	HI (%)
NAA (SS)										
SS_0	3.12 a	0.17 a	8.48 a	5.37 a	29.56 a	92.12 a	44.56 a	4.11 a	2.06 a	39.02 a
SS_1	3.17 a	0.10 a	8.57 a	5.42 a	30.59 a	97.78 a	43.85 b	4.28 a	2.14 a	38.61 a
SS_2	3.27 a	0.05 a	8.60 a	5.95 a	31.68 a	102.40 a	43.81 b	4.53 a	2.26 a	37.59 a
SS_3	3.20 a	0.17 a	8.30 a	5.43 a	29.41 a	93.97 a	42.94 c	4.03 a	2.01 a	37.42 a
SS_4	3.05 a	0.15 a	8.18 a	5.48 a	30.88 a	93.87 a	43.93 b	4.09 a	2.04 a	38.00 a
SS_5	3.22 a	0.08 a	8.34 a	5.72 a	30.86 a	98.85 a	43.91 b	4.30 a	2.15 a	38.21 a
SS_6	3.25 a	0.17 a	8.50 a	5.70 a	30.45 a	98.43 a	44.04 b	4.20 a	2.10 a	37.00 a
Fertilizer (F)										
F_0	2.61 b	0.14 a	8.24 a	4.36 b	28.68 a	74.20 a	45.14 a	3.35 b	1.67 b	38.71 a
F_1	3.27 a	0.17 a	8.60 a	6.05 ab	32.05 a	104.57 a	44.76 b	4.60 a	2.30 a	38.60 a
F_2	3.10 ab	0.05 a	8.29 a	4.93 ab	29.21 a	91.10 a	42.42 d	3.81 ab	1.91 ab	38.97 a
F_3	3.46 a	0.17 a	8.50 a	6.32 a	30.98 a	106.51 a	43.46 c	4.62 a	2.31 a	37.00 a
F_4	3.46 a	0.11 a	8.50 a	6.26 a	31.53 a	107.49 a	43.53 c	4.71 a	2.36 a	36.61 a
CV (%)	10.24	19.50	9.59	4.65	8.90	10.29	6.67	13.82	3.82	12.56
LSD(0.05)	0.55	0.29	0.59	1.86	4.41	20.50	0.33	0.90	0.45	3.68

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.Xb. Combined effects of NAA and N-fertilizer on yield attributes and yield of BARI Gom-25 at harvest during 2015-2016 season.

Treatments (SS × F)	No. of effective tillers/ plant	No. of non-effective tillers /plant	Length of spike (cm)	Dry weight of spikes (g)	No. of grains/ spike	No. of grains/ plant	1000-grain weight (g)	Yield /plant (g)	Yield /ha (t)	HI (%)
SS_0F_0	2.67 h-k	0.08 a	7.80 j	3.23 j	24.25 h	62.33 j	42.50 n	2.61 k	1.30 k	40.35 a-c
SS_1F_0	2.25 jk	0.00	8.18 g-j	3.63 ij	27.33 f-h	61.75 j	44.71 f	2.76 jk	1.38 jk	38.50 c-f
SS_2F_0	2.42 i-k	0.00	8.32 e-j	3.84 h-j	29.89 c-g	69.58 ij	42.88 lm	2.97 jk	1.48 jk	38.86 b-e
SS_3F_0	2.83 f-i	0.25 a	8.07 h-j	4.55 f-j	27.28 f-h	77.42 g-j	44.74 f	3.46 h-k	1.73 h-k	38.26 c-f
SS_4F_0	2.17 k	0.25 a	8.37 d-j	3.91 h-j	28.26 d-h	61.00 j	48.43 a	2.97 jk	1.49 i-k	37.95 c-f
SS_5F_0	2.92 e-i	0.17 a	8.33 e-j	5.69 a-h	32.37 a-d	94.42 c-g	47.44 b	4.46 b-g	2.23 b-g	39.40 b-d
SS_6F_0	3.00 d-h	0.25 a	8.63 a-h	5.64 a-h	31.36 a-f	92.92 d-h	45.30 e	4.21 d-h	2.10 e-h	37.66 c-f
SS_0F_1	3.17 c-h	0.17 a	8.25 f-j	5.39 b-i	30.29 b-g	94.92 c-g	44.68 f	4.25 d-h	2.12 e-h	39.16 b-e
SS_1F_1	3.25 b-g	0.17 a	8.48 b-i	5.55 b-h	30.37 b-g	104.00 a-f	43.70 hi	4.54 a-e	2.27 a-e	42.34 ab
SS_2F_1	3.42 a-e	0.08 a	9.13 a	7.07 ab	35.13 a	115.92 ab	45.83 d	5.26 a-c	2.63 a-d	37.51 c-f
SS_3F_1	3.17 c-h	0.33 a	8.59 a-i	5.82 a-g	31.55 a-f	100.00 a-f	43.64 ij	4.35 d-h	2.18 d-h	37.61 c-f
SS_4F_1	3.17 c-h	0.25 a	8.44 c-i	5.78 a-g	30.63 b-g	96.75 b-g	43.99 gh	4.27 d-h	2.13 e-h	36.99 c-f
SS_5F_1	3.33 a-f	0.08 a	8.33 e-j	6.03 a-f	32.15 a-d	105.50 a-f	46.88 c	4.78 a-e	2.39 a-e	40.31 a-c
SS_6F_1	3.42 a-e	0.08 a	8.98 a-c	6.71 a-e	34.23 a-c	114.92 a-c	44.61 f	4.79 a-d	2.39 a-e	36.27 d-f
SS_0F_2	2.92 e-i	0.00	8.74 a-g	4.74 f-j	30.44 b-g	88.42 e-i	45.38 e	4.00 d-h	2.00 e-h	42.33 ab
SS_1F_2	3.00 d-h	0.08 a	8.94 a-d	5.51 b-h	31.64 a-f	96.42 b-g	43.12 kl	4.15 d-h	2.08 e-h	37.73 c-f
SS_2F_2	3.42 a-e	0.00	8.29 f-j	5.56 b-h	27.45 e-h	95.58 b-g	44.09 g	4.22 d-h	2.11 e-h	37.76 c-f
SS_3F_2	2.75 g-j	0.08 a	8.48 b-i	4.07 g-j	26.66 gh	73.75 h-j	41.33 p	3.05 i-k	1.53 i-k	37.60 c-f
SS_4F_2	3.25 b-g	0.00	7.13 k	4.88 e-j	31.32 a-f	98.92 b-f	41.52 p	4.10 d-h	2.05 e-h	43.18 a
SS_5F_2	3.00 d-h	0.00	8.19 g-j	4.76 f-j	28.94 d-g	85.92 f-i	41.51 p	3.56 g-j	1.78 g-j	38.19 c-f
SS_6F_2	3.33 a-f	0.17 a	8.26 f-j	5.00 d-j	28.04 d-h	98.67 b-f	39.97 r	3.62 f-j	1.81 f-j	35.96 d-f
SS_0F_3	3.25 b-g	0.33 a	8.75 a-g	6.07 a-f	30.59 b-g	98.83 b-f	44.48 f	4.42 d-h	2.21 c-g	36.77 c-f
SS_1F_3	3.58 a-c	0.17 a	8.52 b-i	6.01 a-f	31.85 a-e	112.83 a-d	40.86 q	4.62 a-e	2.31 a-e	38.97 b-e
SS_2F_3	3.25 b-g	0.08 a	9.05 ab	6.40 a-f	34.62 ab	110.58 a-d	43.32 jk	4.78 a-e	2.39 a-e	37.54 c-f
SS_3F_3	3.75 ab	0.08 a	8.29 f-j	6.63 a-e	30.38 bg	113.17 a-d	42.15 o	4.76 a-e	2.38 a-e	36.22 d-f
SS_4F_3	3.42 a-e	0.25 a	8.56 a-i	6.81 a-d	32.09 a-d	108.83 a-e	43.10 kl	4.70 a-e	2.35 a-e	35.00 f
SS_5F_3	3.42 a-e	0.17 a	8.02 ij	6.24 a-f	30.02 c-g	104.83 a-f	43.66 hi	4.56 a-e	2.28 a-e	37.16 c-f
SS_6F_3	3.58 a-c	0.08 a	8.29 f-j	6.04 a-f	27.33 f-h	96.50 b-g	46.67 c	4.52 a-f	2.26 a-f	37.35 c-f
SS_0F_4	3.58 a-c	0.25 a	8.90 a-e	7.45 a	32.21 a-d	116.08 ab	45.74 d	5.31 a-c	2.65 a-c	36.51 d-f
SS_1F_4	3.75 ab	0.08 a	8.75 a-g	6.40 a-f	31.76 a-e	113.92 a-c	46.86 c	5.34 ab	2.67 ab	35.50 ef
SS_2F_4	3.83 a	0.08 a	8.19 g-j	6.87 a-c	31.34 a-f	120.33 a	42.91 lm	5.41 a	2.71 a	36.28 d-f
SS_3F_4	3.50 a-d	0.08 a	8.06 hj	6.11 a-f	31.19 a-f	105.50 a-f	42.85 lm	4.52 a-f	2.26 a-f	37.41 c-f
SS_4F_4	3.25 b-g	0.00	8.41 c-i	6.03 a-f	32.10 a-d	103.83 a-f	42.63 mn	4.41 c-g	2.20 c-g	36.87 c-f
SS_5F_4	3.42 a-e	0.00	8.83 a-f	5.86 a-g	30.83 a-g	103.58 a-f	40.06 r	4.14 d-h	2.07 e-h	35.99 d-f
SS_6F_4	2.92 e-i	0.25	8.35 d-j	5.10 c-i	31.29 a-f	89.17 e-i	43.66 hi	3.88 e-i	1.94 e-i	37.74 c-f
CV (%)	10.24	19.50	9.59	4.65	8.90	10.29	6.67	13.82	3.82	12.56
LSD (0.05)	0.55	0.29	0.59	1.86	4.41	20.50	0.33	0.90	0.45	3.68

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

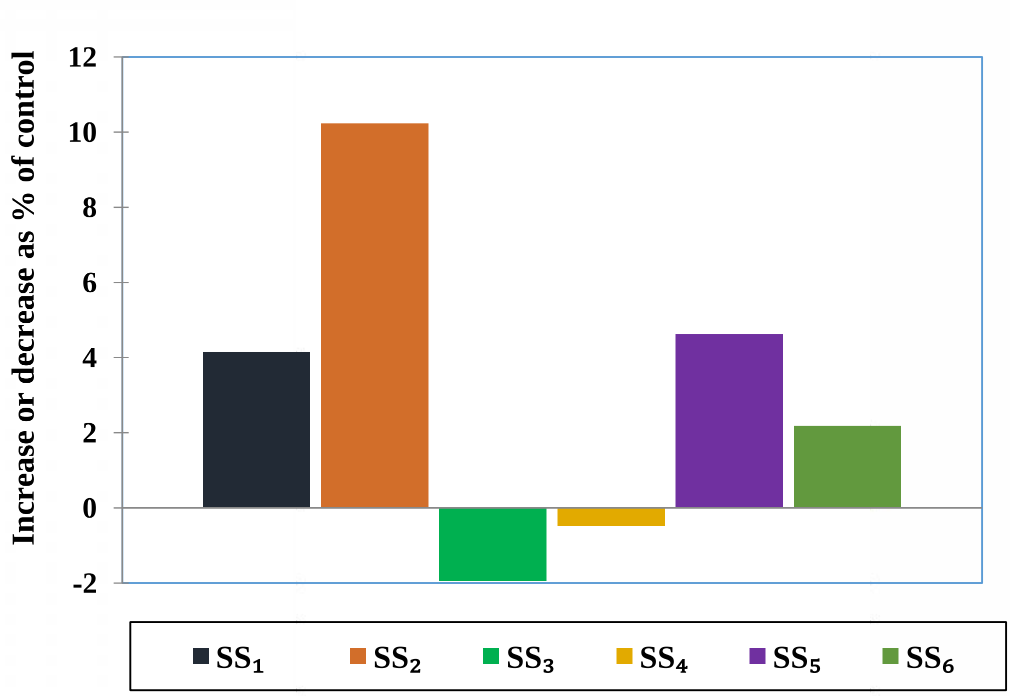

Fig. 4.1a. Yield per plant of wheat as influenced by NAA treatments during 2015-2016 season.

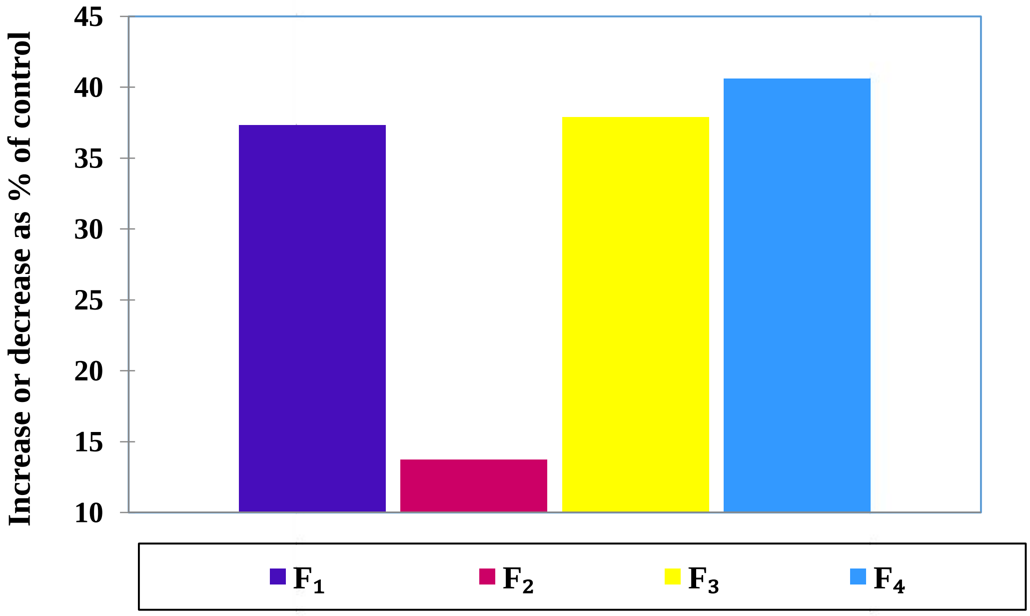

Fig. 4.1b. Yield per plant of wheat as influenced by N-fertilizer treatments during 2015-2016 season.

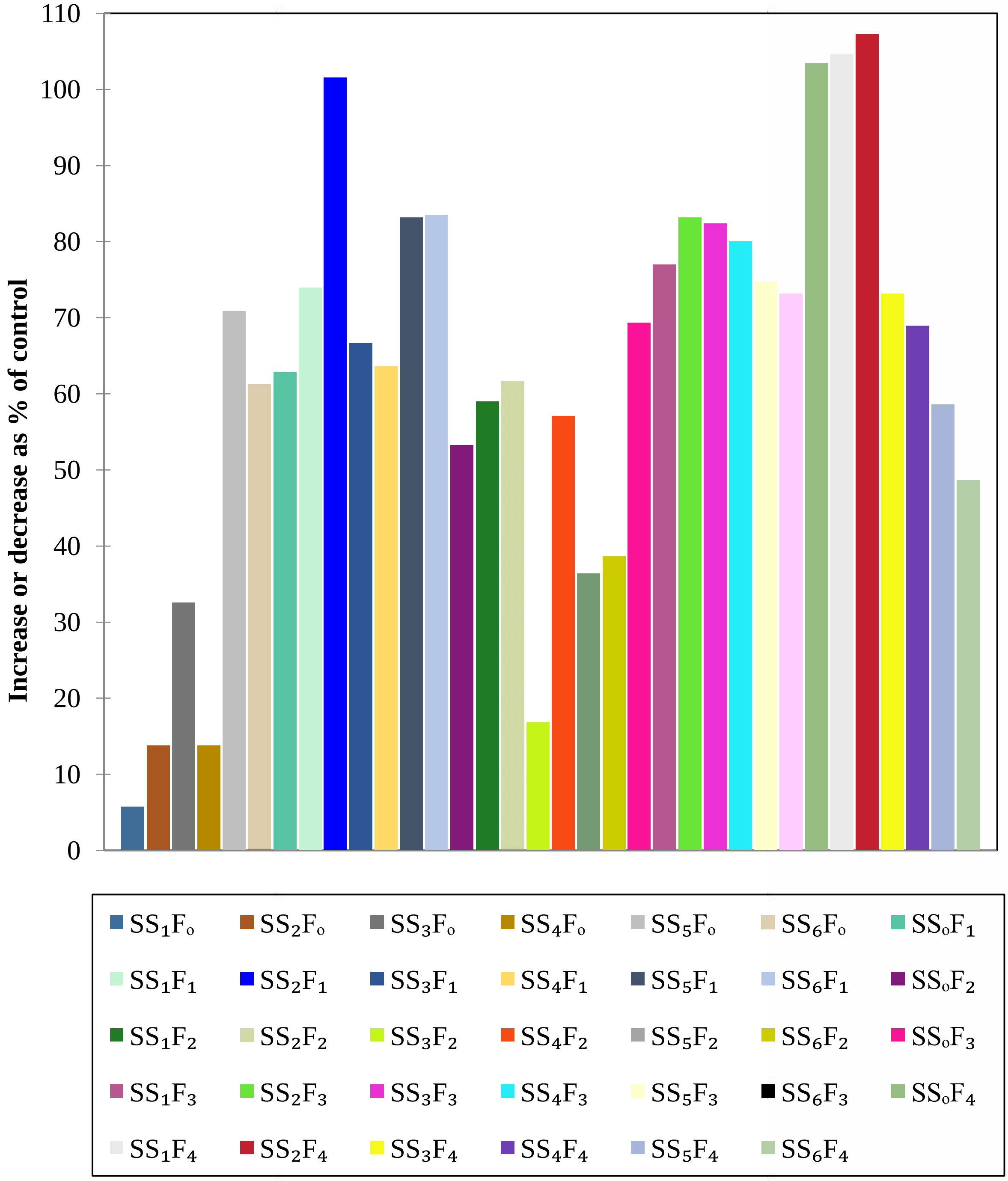

Fig. 4.1c. Yield per plant of wheat as influenced by combined effect of NAA and N-fertilizer during 2015-2016 season.

N-fertilizer

Both increase and decrease in number of non-effective tillers per plant were recorded from different levels of N-fertilizer treatments (Table 4.Xa). The lowest number of non-effective tillers per plant (0.05) was obtained from F_2 treatment which was 64.29 % lower than the control. The maximum increase was noted from both F_1 and F_3 treatments where the increase was 21.43% over the control (Fig. 4.1b).

Combined treatments

Number of non-effective tillers per plant was non-significantly influenced by different combined treatments where, the maximum (0.33) was obtained from both SS_3F_1 and SS_0F_3 treatments (Table 4.Xb). However, eight treatments *viz.* SS_1F_0, SS_2F_0, SS_0F_2, SS_2F_2, SS_4F_2, SS_5F_2, SS_4F_4 and SS_5F_4 did not produce any non-effective tillers per plant.

4.2.2.3 Length of spike

NAA

Length of spike was responded both positively and negatively following foliar NAA treatments but variations among the treatments were non-significant (Table 4.Xa). The shortest (8.18 cm) and longest (8.60 cm) length of spike was observed from SS_4 and SS_2 treatments respectively.

N-fertilizer

Application of different doses of N-fertilizer had inducing effect on the length of spike of BARI Gom-25 but with statistically similar value (Table 4.Xa). The maximum increase due to F_1 treatments was 4.37% followed by both F_3 and F_4 treatments (3.16%).

Combined treatments

Foliar application of NAA at varying N-levels had significant responses on length of spike of some treatments (Table 4.Xb). Length of spike increased following all combined treatments except SS_4F_2 (Fig. 4.1c). Significantly longest spike (9.13 cm) was recorded from SS_2F_1 treatment (17.05% higher over the control) although statistically identical to SS_6F_0, SS_3F_1, SS_6F_1, SS_0F_2, SS_1F_2, SS_0F_3, SS_2F_3, SS_4F_3, SS_0F_4, SS_1F_4 and SS_5F_4 treatments.

4.2.2.4 Dry weight of spike

NAA

Dry weight of spike was positively responded by foliar NAA treatments but with statistically similar value (Table 4.Xa). The maximum increase in dry weight of spike due to SS_2 treatment was 10.80% followed by SS_5 (6.52%), SS_6 (6.15%), 2.05% (SS_4) and SS_1 (0.93%) respectively (Fig. 4.1a).

N-fertilizer

Application of different doses of N-fertilizer had both significant and non-significant responses on dry weight of spike (Table 4.Xa). Maximum dry weight of spike obtained from F_3 treatment was 44.95% higher over the control followed by F_4 (44.58%) and the increases due to these two treatments were statistically similar to F_1 and F_2 but different from control (Fig. 4.1b).

Combined treatments

Foliar application of NAA at varying N-levels had stimulatory effects on dry weight of spikes following all the treatments with significant variations (Table 4.Xb). The maximum increase in dry weight of spikes due to SS_4F_0 treatment was 130.65% followed by SS_2F_1 (118.89%) and were significantly higher than most of the treatments (Fig. 4.1c).

4.2.2.5 Number of grains per spike and per plant

NAA

Foliar application of NAA had stimulating effects on the number of grains per spike and grains per plant but with non-significant variations although the least number of grains per spike was noted from SS_3 treatment. The maximum increase in number of grains per spike and grains per plant was obtained from SS_2 treatment and were 7.17 and 11.16% higher over the control (Fig. 4.1a).

N-fertilizer

Application of various levels of N-fertilizers resulted higher number of grains per spike and grains per plant (Table 4.Xa). The number of grains per spike increased by 11.75, 9.94, 8.02 and 1.85% due to F_1, F_4, F_3 and F_2 treatments respectively. Whereas, the maximum increase in number of grains per plant due to F_4 treatment was 44.87% followed by F_3 (43.54%), F_1 (40.93%) and F_2 (22.78) respectively.

Combined treatments

Combined application of NAA and N-fertilizer had significant effects on the number of grains per spike and grains per plant (Table 4.Xb). Number of grains per spike was recorded higher following all treatments. Number of grains per spike obtained from SS_2F_1 treatment was significantly higher than most of the treatments and the increase due to this treatment was 44.87% (Fig. 4.1c). Number of grains per plant was also influenced positively following all treatments except SS_1F_0 and SS_4F_0 and the highest increase due to SS_2F_4 treatment was 93.05% followed by SS_0F_4 (86.23%).

4.2.2.6 1000-grain weight

NAA

Weight of 1000-grain significantly decreased due to different NAA treatments (Table 4.Xa). The maximum decrease in 1000-grain weight, 3.64% was recorded due to SS_3 treatment, whereas, the minimum 1.17% was due to SS_6 (Fig. 4.1a).

N-fertilizer

Various levels of N-fertilizer significantly decreased 1000-grain weight of BARI Gom-25 (Table 4.Xa). The maximum decrease was observed from F_2 treatment (6.03%) followed by F_3 (3.72%), F_4 (3.57%) and F_1 (0.84%) respectively (Fig. 4.1b).

Combined treatments

Combined application of NAA and N-fertilizer had mostly inducing effects on 1000-grain weight of BARI Gom-25 (Table 4.Xb). Maximum 1000-grain weight was found from SS_4F_0 treatment which was statistically different from all other treatments and was 13.95% higher over the control. The second highest 1000-grain weight was obtained from SS_5F_0 treatment which was also significantly different from all other treatments and the increase following this treatment was 11.62% over the control. The minimum was recorded from SS_6F_2 treatment which was statistically at par with SS_5F_4 and also different from all other treatments.

4.2.2.7 Yield per plant and per hectare

NAA

Yield per plant and yield per hectare due to foliar application of NAA treatments varied non-significantly among the treatments (Table 4.Xa). The maximum yield per plant (4.53 g) was noted from SS_2 treatment followed by SS_5, SS_1 and SS_6 and the increases recorded were 10.22, 4.62, 4.13 and 2.19% respectively. However, yield per plant was reduced by 1.95 and 0.49% due to SS_3 and SS_4 treatments respectively. Similar trend of increase and decrease was also observed in of case yield per hectare and the increases were 9.71, 4.37, 3.88 and 1.94% due to SS_2, SS_5, SS_1 and SS_6 treatments respectively (Fig. 4.1a).

N-fertilizer

Application of different doses of N-fertilizers resulted higher yield per plant and yield per hectare and were significant following all treatments except F_2 (Table 4.Xa). Yield per plant increased by 40.60, 37.91, 37.31 and 13.73% due to F_4, F_3, F_1 and F_2 treatments respectively. Similar result of increases following different N-treatments was also observed in case of yield per hectare and the increases due to F_4, F_3, F_1 and F_2 treatments were 41.32, 38.32, 37.72 and 14.37% respectively (Fig. 4.1b).

Combined treatments

Foliar application of NAA in combination with various doses of N-fertilizer resulted higher yield per plant and yield per hectare with significant variations (Table 4.Xb). Significantly maximum yield per plant (5.41 g) and per hectare (2.71 t) was obtained from SS_2F_4 treatment although statistically identical to SS_1F_1 , SS_2F_1, SS_5F_1, SS_6F_1, SS_1F_3, SS_2F_3, SS_3F_3, SS_4F_3, SS_5F_3, SS_6F_3, SS_0F_4 SS_1F_4 and SS_3F_4 treatments. Yield per plant increased by 107.28, 104.60, 103.45 and 101.53% due to SS_2F_4, SS_1F_4, SS_0F_4 and SS_2F_1 treatments respectively. In this case although, the yield per plant obtained from SS_2F_4 treatment was 2.85% higher than SS_2F_1 (25 ppm NAA in combination with 25% of the recommended dose of N-fertilizer) but was statistically not different from each other. However, the range of increases in yield per hectare was 6.15 to 108.46%. The maximum and the minimum increases were recorded from SS_2F_4 and SS_1F_0 treatments respectively (Fig. 4.1c).

4.2.2.8 Harvest index

NAA

Harvest index (HI) was affected non-significantly and decreased due to all NAA treatments (Table 4.Xa). The maximum decrease was recorded from SS_6 treatment and it was 5.18% lower than the control (Fig. 4.1a).

N-fertilizer

Both increase and decrease in HI of BARI Gom-25 were observed following different N-levels but with non-significant variations (Table 4.Xa). The only increase in HI was recorded from F_2 treatment and it was 0.67% higher than the control. However, HI was decreased by 0.28, 4.42 and 5.43% following F_1, F_3 and F_4 treatments respectively (Fig. 4.1b).

Combined treatments

Data in Table 4.Xb indicate that combined application of NAA and N-fertilizer had both stimulatory and inhibitory effects on HI of BARI Gom-25 (Table 4.Xb). The highest increases in HI, 43.18% was recorded from SS_4F_2 treatment followed by SS_1F_1 (42.34%), SS_0F_2 (42.33%) and SS_5F_1 (40.31%) respectively (Fig. 4.1c). Harvest index following these treatments were non-significant in comparison to control plant value.

4.2.3 Effects of NAA and N-fertilizer on biochemical parameters

4.2.3.1 Effects of NAA and N-fertilizer on pigment contents of leaves

Both NAA and fertilizer as well as their combined effect had significant influences upon pigment contents of leaves at different stages except due to NAA on chlorophyll b at grain filling stage (Table 4.XIa and 4.XIb).

NAA

Pigment contents of leaves were positively influenced by NAA application at tillering stage but with few exceptions (Table 4.XIa).

At this stage all treatments resulted significantly higher chlorophyll a (chl. a) content except SS_1 treatment and the maximum value (0.15 mg/g) was recorded from SS_4 treatment. The range of increases were 12.50 to 175% whereas, the only decrease due to SS_1 was 50%. Chlorophyll b (chl. b) content although obtained highest from SS_6 treatment but statistically not different from control. The lowest was recorded from SS_1 treatment which was statistically identical to all other treatment except SS_6. All NAA treatments had resulted significantly higher carotenoids content of leaves at this stage where, the highest increase was 66.42% (SS_6) followed by 63.75% (SS_4) and both these treatments were statistically identical. At flowering stage, significantly higher chl. a content of leaves was obtained from SS_4 and SS_6 treatments where the maximum increase due to SS_4 was 25% over the control. At this stage, chl. b and carotenoids content obtained from SS_5 treatment although higher than control but statistically similar. Both increase and decrease in pigment contents of leaves were observed at grain filling stage where, the maximum chl. a content (0.20 mg/g) was found from SS_4 treatment which was statistically not different from control. At this stage, all treatments resulted statistically similar value in case of chl. b content however, carotenoids content of leaves (6.61 mg/g) was recorded maximum from SS_5 which was significantly different from all other treatments.

N-fertilizer

Results presented in Table 4.XIa showed that application of various doses of N-fertilizers had significant responses on pigment contents of leaves at different stages. At the tillering stage, all the pigment contents were recorded maximum following F_2 treatment whereas, minimum due to F_1 and the treatment F_2 resulting maximum chl. a and carotenoids were significantly different from the rest of the treatments. But in case of chl. b although the maximum and minimum recorded from F_2 and F_1 are significantly different from each other but statistically similar to control. At flowering stage, significantly higher chl. a (57.14%) and carotenoids (8.30%) contents were obtained from F_4 treatment whereas, chl. b content was affected with similar statistical values. Results revealed that F_1 treatment also produced least values in pigment contents of leaves at this stage. At grain filling stage, significantly higher amount of chl. a was found from F_2, F_3 and F_4 treatments and increased by 33.33, 46.67 and 33.33% respectively.

Table 4.XIa. Effects of NAA and N-fertilizer on pigment contents (mg/g) of leaves of BARI Gom-25 at three different stages during 2015-2016 season.

Treatments	Tillering stage			Flowering stage			Grain Filling stage		
	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids
NAA (SS)									
SS_0	0.08 c	0.09 ab	4.11 f	0.20 b	0.07 ab	6.70 a	0.19 ab	0.07 a	6.05 b
SS_1	0.03 d	0.06 b	4.18 e	0.19 b	0.06 bc	4.76 c	0.18 bc	0.06 a	5.81 b
SS_2	0.13 ab	0.07 b	5.88 c	0.19 b	0.05 c	5.52 b	0.16 d	0.07 a	5.22 c
SS_3	0.11 b	0.07 b	5.04 d	0.20 b	0.06 bc	6.36 a	0.19 ab	0.07 a	5.96 b
SS_4	0.15 a	0.09 ab	6.73 ab	0.25 a	0.06 bc	6.39 a	0.20 a	0.07 a	6.09 b
SS_5	0.13 ab	0.11 ab	6.51 b	0.20 b	0.08 a	6.78 a	0.19 ab	0.07 a	6.61 a
SS_6	0.13 ab	0.13 a	6.84 a	0.24 a	0.06 bc	6.64 a	0.17 cd	0.04 a	5.37 c
Fertilizer (F)									
F_0	0.08 c	0.10 ab	4.55 d	0.21 c	0.07 a	6.87 b	0.15 c	0.08 ab	5.67 b
F_1	0.04 d	0.05 b	4.47 d	0.02 d	0.04 b	3.37 c	0.13 d	0.09 a	6.13 a
F_2	0.22 a	0.12 a	7.79 a	0.25 b	0.07 a	6.72 b	0.20 b	0.05 b	5.79 b
F_3	0.12 b	0.10 ab	5.92 b	0.24 b	0.07 a	6.41 b	0.22 a	0.06 ab	5.96 ab
F_4	0.09 c	0.08 ab	5.32 c	0.33 a	0.07 a	7.44 a	0.20 b	0.05 b	5.65 b
CV (%)	10.21	9.57	14.05	18.03	17.96	12.50	19.63	14.44	9.32
LSD(0.05)	0.02	0.05	0.32	0.01	0.01	0.48	0.01	0.03	0.33

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XIb. Combined effects of NAA and N-fertilizers on pigment contents (mg/g) of leaves of BARI Gom-25 at three different stages during 2015-2016 season.

Treatments	Tillering stage			Flowering stage			Grain Filling stage		
(SS × F)	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids
SS_0F_0	0.09 e	0.16 a-d	1.95 p	0.22 ij	0.08 bc	7.95 c-e	0.21 ef	0.12 a	7.30 bc
SS_1F_0	0.08 ef	0.11 d-g	4.40 jk	0.21 j	0.06 de	6.43 lm	0.08 op	0.11 a	4.83 n
SS_2F_0	0.18 d	0.12 d-f	6.80 e	0.06 o	0.02 hi	2.87 u	0.07 p	0.06 cd	3.30 q
SS_3F_0	0.08 ef	0.12 d-f	5.50 g	0.13 lm	0.07 cd	6.49 l	0.21 ef	0.11 a	7.57 b
SS_4F_0	0.05 gh	0.11 d-g	5.95 f	0.35 b	0.07 cd	7.85 c-f	0.13 m	0.06 cd	4.98 l-n
SS_5F_0	0.02 ij	0.03 i	2.62 o	0.14 l	0.12 a	8.01 b-d	0.18 hi	0.06 cd	6.85 d-f
SS_6F_0	0.02 ij	0.05 hi	4.60 ij	0.34 b	0.08 bc	8.48 ab	0.13 m	0.04 cd	4.86 n
SS_0F_1	0.01 j	0.03 i	2.76 no	0.04 p	0.12 a	4.92 pq	0.14 lm	0.07 bc	5.86 gh
SS_1F_1	0.02 ij	0.04 i	4.79 hi	0.02 q	0.05 ef	1.25 w	0.21 ef	0.06 cd	6.80 ef
SS_2F_1	0.05 gh	0.03 i	4.57 ij	0.01 q	0.01 i	4.78 q	0.09 no	0.10 ab	4.85 n
SS_3F_1	0.06 fg	0.03 i	4.68 ij	0.02 q	0.03 gh	4.24 r	0.10 n	0.11 a	6.62 f
SS_4F_1	0.03 h-j	0.07 f-i	4.74 i	0.01 q	0.01 i	2.36 v	0.13 m	0.11 a	5.37 i-k
SS_5F_1	0.03 h-j	0.07 f-i	5.07 h	0.02 q	0.02 hi	3.40 s	0.13 m	0.13 a	8.09 a
SS_6F_1	0.09 e	0.07 f-i	4.71 ij	0.02 q	0.02 hi	2.64 uv	0.15 kl	0.04 cd	5.29 j-l
SS_0F_2	0.06 fg	0.07 f-i	5.56 g	0.29 ef	0.07 cd	7.41 f-i	0.14 lm	0.04 cd	4.42 o
SS_1F_2	0.02 ij	0.07 f-i	4.18 kl	0.10 n	0.04 fg	3.36 s	0.17 ij	0.04 cd	5.21 j-m
SS_2F_2	0.38 a	0.10 e-h	9.42 a	0.19 k	0.06 de	5.51 no	0.20 fg	0.06 cd	4.88 mn
SS_3F_2	0.38 a	0.11 d-g	9.35 a	0.30 de	0.08 bc	7.63 d-h	0.21 ef	0.04 cd	5.11 k-n
SS_4F_2	0.31 b	0.11 d-g	8.83 b	0.28 fg	0.08 bc	7.06 i-k	0.24 bc	0.06 cd	7.13 c-e
SS_5F_2	0.17 d	0.16 a-d	8.42 c	0.30 de	0.09 b	8.30 a-c	0.25 b	0.06 cd	7.16 cd
SS_6F_2	0.25 c	0.19 ab	8.79 b	0.28 fg	0.09 b	7.76 d-g	0.22 de	0.05 cd	6.61 f
SS_0F_3	0.05 gh	0.07 f-i	3.59 m	0.12 m	0.04 fg	5.31 op	0.24 bc	0.06 cd	6.12 g
SS_1F_3	0.04 g-i	0.06 g-i	3.47 m	0.31 cd	0.06 de	4.88 pq	0.21 ef	0.05 cd	5.47 ij
SS_2F_3	0.04 g-i	0.06 g-i	4.00 l	0.23 i	0.06 de	5.95 mn	0.24 bc	0.06 cd	6.17 g
SS_3F_3	0.04 g-i	0.07 f-i	2.99 n	0.26 h	0.07 cd	6.82 j-l	0.24 bc	0.05 cd	6.15 g
SS_4F_3	0.31 b	0.14 b-e	9.36 a	0.31 cd	0.07 cd	7.47 e-i	0.27 a	0.07 bc	6.78 f
SS_5F_3	0.27 c	0.11 d-g	8.74 bc	0.22 ij	0.09 b	7.17 h-j	0.16 jk	0.04 cd	4.88 mn
SS_6F_3	0.08 ef	0.20 a	9.29 a	0.27 gh	0.07 cd	7.31 g-i	0.21 ef	0.06 cd	6.12 g
SS_0F_4	0.18 d	0.11 d-e	6.66 e	0.30 de	0.03 gh	7.91 c-e	0.21 ef	0.05 cd	6.54 f
SS_1F_4	0.02 ij	0.03 i	4.07 l	0.32 c	0.09 b	7.89 c-f	0.25 b	0.05 cd	6.76 f
SS_2F_4	0.02 ij	0.03 i	4.62 ij	0.45 a	0.11 a	8.52 a	0.19 gh	0.06 cd	5.67 hi
SS_3F_4	0.01 j	0.02 i	2.66 o	0.30 de	0.07 cd	6.60 kl	0.17 ij	0.05 cd	4.34 o
SS_4F_4	0.03 h-j	0.02 i	4.76 hi	0.32 c	0.07 cd	7.18 h-j	0.22 de	0.05 cd	6.18 g
SS_5F_4	0.17 d	0.18 a-c	7.69 d	0.31 cd	0.08 bc	7.02 i-k	0.23 cd	0.07 bc	6.09 g
SS_6F_4	0.19 d	0.13 c-e	6.81 e	0.30 de	0.06 de	7.00 i-k	0.14	0.03 d	3.95 p
CV (%)	10.21	9.57	14.05	18.03	17.96	12.50	19.63	14.44	9.32
LSD (0.05)	0.02	0.05	0.32	0.01	0.01	0.48	0.01	0.03	0.33

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Different doses of N-fertilizer resulted higher carotenoids content of leaves where, F_1 treatment produced 8.11% higher value over the control. However, the maximum chl. b was obtained from F_1 and the minimum from F_2 and both these are significantly different from each other but statistically at par with the control.

Combined treatments

Pigment contents of leaves were significantly influenced by NAA at varying N-levels (Table 4.XIb). At tillering stage, chl. a content of leaves obtained maximum following two treatments, SS_2F_2 and SS_3F_2 and were significantly different from all other treatments. The least amount of chl. a was observed from the leaves of SS_0F_1 and SS_3F_4 treatments and were significantly different from control. Combined treatments had retarding effect on chl. b content of leaves although SS_6F_2 and SS_6F_3 treatment resulted higher values but statistical identical to control. Carotenoids content of leaves were significantly higher following all combined treatments where the maximum increase was 383.08% (SS_2F_2) followed by 380% (SS_4F_3).

At flowering stage, the maximum increase in chl. a content due to SS_2F_4 treatment was 104.55% over the control followed by 59.09% (SS_4F_0) and 55.55% (SS_6F_0) respectively (Table 4.XIb). The maximum amount of chl. b content of leaves was observed from two treatments, SS_5F_0 and SS_0F_1. Increases in chl. b content obtained due to SS_5F_0, SS_0F_1 and SS_2F_4 treatments were 50.0, 50.0 and 37.50% over the control respectively. Significantly maximum carotenoids content of leaves was observed from SS_2F_4 treatment which was 7.17% higher over the control followed by 6.67% (SS_6F_0), 4.40% (SS_5F_2) and 0.75% (SS_5F_0) respectively.

At grain filling stage, only a few combined treatments (SS_4F_2, SS_5F_2, SS_0F_3, SS_2F_3, SS_3F_3, SS_4F_3, SS_1F_4, SS_5F_4) had significant beneficial effect on chl. a content of leaves. But in case of chl. b content of leaves it was affected almost negatively except only SS_5F_1. Carotenoids content of leaves at grain filling stage was significantly maximum (8.09 mg/g) due to SS_5F_1 treatment where it was 10.82% higher over the control. However, the highest decrease in carotenoids content was 54.79% due to SS_2F_0 treatment.

4.3 Experiment 3 carried out during the season of 2015-2016

Experiment 3 was conducted with four lower concentrations of NAA as seed soaking treatment in combination with recommended dose of N-fertilizer to find out the suitable concentration where, SO_0, SO_1, SO_2 and SO_3 represent seed soaked with distilled water, 10 ppm, 20 ppm and 30 ppm NAA respectively. In this experiment seeds were sown on November 15 (optimum time).

4.3.1 Effects of NAA as seed soaking treatment on physiological parameters

4.3.1.1 Plant height

Application of NAA as seed soaking treatment had resulted taller plant throughout the growth ages where, the tallest plant was obtained from SO_1 treatment (Table 4.XII). At early stages of growth (30-60 DAS), all treatments produced statistically similar height but after the age of 60 DAS plant height was significantly higher following all treatments. Height of BARI Gom-25 increased by 4.09, 3.96 and 3.97% following SO_1, SO_2 and SO_3 treatments respectively.

4.3.1.2 Number of tillers per plant

Number of tillers per plant was significantly influenced by seed soaking treatment of NAA throughout the growing periods (Table 4.XIII). At the age of 30 DAS, all concentrations of NAA treatment produced significantly higher number of tillers per plant where the maximum was obtained from SO_1 treatment. Results also revealed that after the age of 30 DAS SO_1 treatment produced maximum number of tillers per plant up to the harvest which was statistically not at par with those of any other treatment. The minimum number of tillers per plant was noted from SO_3 treatment and it was also significantly different from those of the control plant values. The number of tillers per plant recorded at harvest due to SO_1 treatment was 7.88% higher over the control.

4.3.1.3 Number of leaves per plant

Number of leaves per plant was affected significantly following different seed soaking treatments at various growth stages (Table 4.XIV).

Table 4.XII. Effects of NAA as seed soaking treatments on plant height (cm) of BARI Gom-25 at different ages during 2015-2016 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
SO_0	52.05	74.24 a	91.07 a	91.45 b	91.78 b	91.78 b
SO_1	53.61	77.75 a	93.94 a	95.18 a	95.41 a	95.43 a
SO_2	52.27	75.67 a	93.84 a	94.03 a	94.23 a	94.27 a
SO_3	52.22	77.00 a	93.75 a	93.98 a	94.09 a	94.10 a
CV (%)	6.94	7.90	5.40	4.68	4.06	3.02
LSD (0.05)	NS	5.42	4.49	3.66	3.27	2.24

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XIII. Effects of NAA as seed soaking treatments on number of tillers per plant of BARI Gom-25 at different ages during 2015-2016 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
SO_0	4.25 b	5.83 b	6.00 b	5.50 b	5.42 b	5.33 b
SO_1	4.67 a	6.08 a	7.00 a	6.25 a	6.08 a	5.75 a
SO_2	4.42 a	5.75 bc	5.75 b	5.00 b	4.92 c	5.08 b
SO_3	4.33 a	5.58 c	5.25 c	4.08 c	4.17 c	4.17 c
CV(%)	11.28	12.34	3.26	3.36	3.78	8.93
LSD(0.05)	0.34	0.23	0.64	0.71	0.33	0.39

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XIV. Effects of NAA as seed soaking treatments on number of leaves per plant of BARI Gom-25 at different ages during 2015-2016 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
SO_0	19.33 c	24.83 b	22.08 a	13.67 ab	13.25 ab	14.08 b
SO_1	22.25 a	26.67 a	24.00 a	16.33 a	15.58 a	14.42 a
SO_2	21.50 ab	25.33 a	22.00 ab	13.00 ab	12.92 ab	12.00 c
SO_3	19.67 bc	25.42 a	17.33 b	10.33 b	10.75 b	10.58 d
CV(%)	11.97	12.42	3.66	3.70	13.05	9.44
LSD(0.05)	1.84	1.37	4.73	4.12	3.31	0.32

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XV. Effects of NAA as seed soaking treatments on total dry matter (g) per plant of BARI Gom-25 at different ages during 2015-2016 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
SO_0	1.27 c	3.76 b	8.53 c	9.80 c	11.62 b	12.57 b
SO_1	1.81 a	4.73 a	10.00 a	11.54 a	13.12 a	15.53 a
SO_2	1.51 b	4.06 b	8.95 b	10.36 b	11.96 b	13.23 b
SO_3	1.20 c	4.06 b	8.42 c	9.42 c	10.86 c	12.28 b
CV(%)	12.77	15.34	8.13	11.50	8.32	14.70
LSD(0.05)	0.20	0.34	0.34	0.53	0.44	1.21

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

At 30 and 45 DAS all treatments had resulted significantly higher number of leaves per plant except due to SO_3 treatment at 30 DAS. At the age of 60-90 DAS number of leaves per plant due to SO_1 treatment although recorded maximum but were statistically identical to control. At this stages, the maximum decrease in number of leaves per plant was observed from SO_3 treatment. Number of leaves per plant due to SO_1 treatment increased by 2.41% at harvest.

4.3.1.4 Total dry matter per plant

Application of NAA as seed soaking treatment had both stimulatory and retarding effects on total dry matter (TDM) per plant of BARI Gom-25 depending on the concentration of NAA (Table 4.XV). Significantly higher dry matter per plant was obtained from SO_1 treatment throughout the growth ages where, the minimum was found from SO_3 treatment except at the age of 45 DAS. The TDM per plant due to SO_1 treatment increased by 42.52, 25.80, 17.23, 17.76, 12.91 and 23.55% at 30, 45, 60, 75, 90 DAS and at harvest respectively and followed by SO_2.

4.3.2 Effects of NAA as seed soaking treatment on yield attributes and yield

Yield attributes and yield of BARI Gom-25 were affected both significantly and non-significantly following different NAA treatments (Table XVI).

4.3.2.1 Number of effective tillers (spikes) per plant

Both increase and decrease in the number of effective tillers per plant was obtained from different seed soaking treatments (Table XVI). Application of SO_1 treatment resulted significantly maximum number of effective tillers per plant (5.75) where the increase was 13.19% over the control. Number of effective tillers per plant decreased by 3.15 and 21.25% due to SO_2 and SO_3 treatments respectively.

4.3.2.2 Number of non-effective tillers per plant

Seed soaking treatments of NAA had non-significant effect on number of non-effective tillers per plant and decreased due to all the treatments (Table XVI). The lowest number of non-effective tillers per plant (0.00) was obtained from SO_1 treatment.

4.3.2.3 Length of spike

Length of spike significantly increased due to the application of NAA treatment where, the maximum increase was obtained from SO_3 treatment (8.54%) followed by SO_2 (5.17%) and SO_1 (2.92) treatments respectively (Table XVI).

4.3.2.4 Dry weight of spike

Seed soaking treatments of NAA had resulted higher dry weight of spike except SO_3 treatment but with statistically similar effect. The maximum increase due to SO_1 treatment was 15.38% followed by SO_2 treatment (Table XVI).

4.3.2.5 Number of grains per spike and plant

Number of grains per spike was recorded higher due all seed soaking treatments of NAA but with non-significant variations. However, number of grains per plant were recorded higher from all the treatments except due to SO_3 (Table XVI). Maximum increase in number of grains per plant was observed from SO_1 (9.86%) treatment.

4.3.2.6 1000-grain weight

Both increase and decrease in 1000-grain weight was observed following NAA treatments (Table XVI). The maximum 1000-grain weight (46.19 g) was obtained from SO_2 treatment followed by SO_3 (45.85 g) whereas, the minimum was found from SO_1 treatment (45.30 g).

4.3.2.7 Yield per plant and per hectare

Yield per plant and yield per hectare were both significantly and non-significantly influenced by seed soaking of NAA treatments (Table XVI). Significantly higher yield per plant and per hectare were obtained from $S0_1$ treatment. Yield per plant and per hectare although increased due to $S0_2$ treatment but not statistically different from control. Application of $S0_1$ treatment resulted 16.08 and 16.38% higher yield per plant and yield per hectare over the control (Fig. 4.2).

4.3.2.8 Harvest index

Harvest index was influenced non-significantly following different seed soaking treatments. The increase in HI was obtained from $S0_2$ treatment whereas, decreased were due to other two treatments (Table XVI).

Table 4.XVI. Effects of NAA as seed soaking treatment on yield attributes and yield of BARI Gom-25 at harvest during 2015-2016 season.

Treatments	No. of effective tillers/ plant	No. of non-effective tillers /plant	Length of spike (cm)	Dry weight of spikes (g)	No. of grains/ spike	No. of grains/ plant	1000-grain weight (g)	Yield/ plant (g)	Yield/ Ha (t)	HI (%)
SO_0	5.08 b	0.25	8.90 c	8.00 ab	32.39	168.84 b	45.83	7.09 bc	3.54 bc	57.55
SO_1	5.75 a	0.00	9.16 b	9.23 a	32.69	185.48 a	45.30	8.23 a	4.12 a	54.61
SO_2	4.92 b	0.17	9.36 b	9.22 a	34.26	169.07 b	46.19	8.06 ab	4.03 ab	60.56
SO_3	4.00 c	0.17	9.66 a	7.08 b	34.91	140.34 c	45.85	6.46 c	3.23 c	53.35
CV(%)	8.15	24.45	9.55	4.06	15.11	13.00	3.55	9.38	9.38	13.37
LSD(0.05)	0.61	NS	0.23	1.52	NS	14.93	NS	1.12	0.55	NS

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

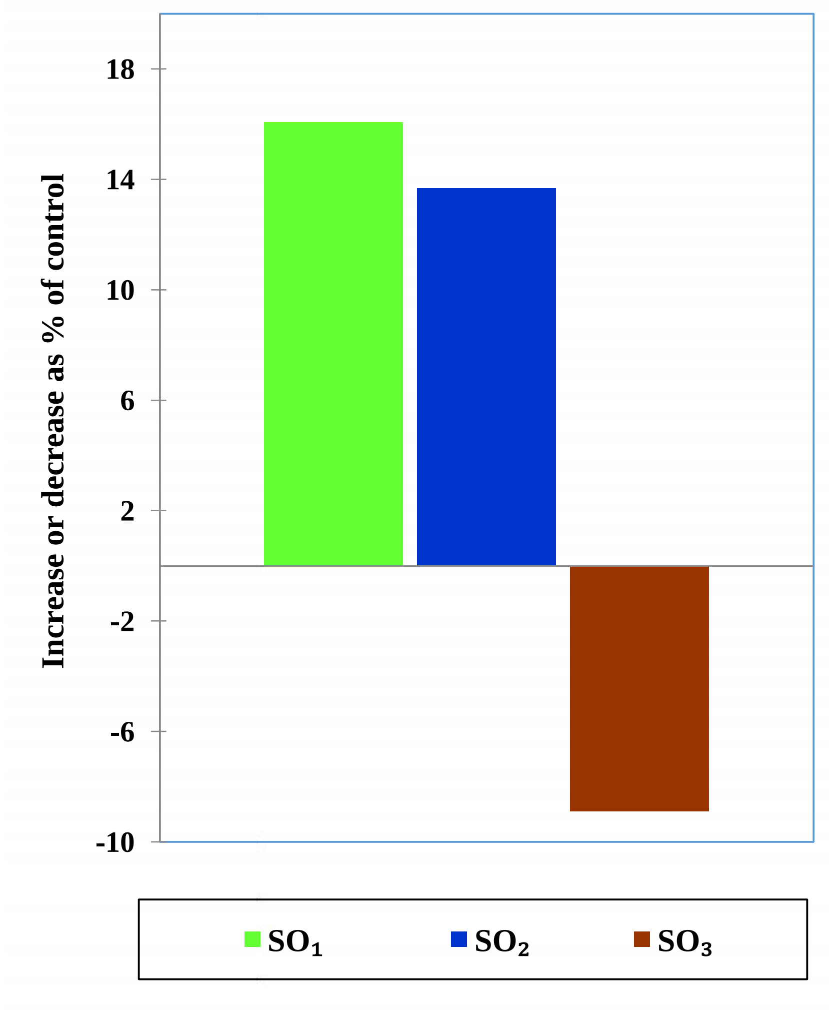

Fig. 4.2. Yield per plant of BARI Gom-25 as influenced by seed soaking treatments of NAA during 2015-2016 season.

4.3.3 Effects of NAA as seed soaking treatment on biochemical parameters

4.3.3.1 Effects of NAA as seed soaking treatment on pigment contents of leaves

Application of NAA as seed soaking treatment had significant effect on pigment contents of leaves (Table XVII). At tillering stage, all treatments resulted significantly higher amount of pigment contents except due to SO_2 treatment on chl. b. The maximum chl. a, chl. b and carotenoids contents due to SO_1 treatment were 310, 12.5 and 30.80% higher over the control respectively. At flowering stage, significantly higher value of chl. a content was observed from SO_2 treatment which was 57.14% higher over the control. However, chl. a content decreased by 53.13% following both SO_1 and SO_3 treatments. At this stage, although chl. b and carotenoids contents were recorded highest from SO_1 treatment but statistically not different from that of control. Significantly lower chl. b and carotenoids were also found from SO_3 treatment at flowering stage. At grain filling stage, seed soaking treatments produced significantly higher pigment contents of leaves with an exception in case of chl. b content (Table XVII).

Table 4.XVII. Effects of NAA as seed soaking treatment on pigment contents (mg/g) of leaves of BARI Gom-25 at three different stages during 2015-2016 season.

Treatments	Tillering stage			Flowering stage			Grain filling stage		
	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids
SO_0	0.10 d	0.16 b	2.37 d	0.49 b	0.25 a	4.46 a	0.12 c	0.16 c	2.75 c
SO_1	0.41 a	0.18 a	3.10 a	0.32 c	0.27 a	4.48 a	0.49 a	0.21 b	4.91 a
SO_2	0.38 b	0.16 b	2.84 b	0.77 a	0.24 a	4.42 a	0.48 a	0.19 bc	4.70 ab
SO_3	0.35 c	0.17 ab	2.76 c	0.32 c	0.11 b	3.93 b	0.40 b	0.83 a	4.49 b
CV (%)	4.24	8.02	9.66	13.54	15.10	9.45	13.14	8.07	12.08
LSD(0.05)	0.01	0.01	0.04	0.10	0.04	0.31	0.05	0.03	0.21

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

4.4 Experiment 4 carried out during the season of 2016-2017

Experiment 4 was carried out with best foliar NAA treatment (20 ppm) and selected seed soaking treatment (10 ppm) in combination with varying N-levels at timely (November 15) and 7 days late sown condition (November 22). There were nine selected treatments in this experiment. In the texts, tables and figures control and F_4 means without NAA and N-fertilizer and 100% of the recommended N-fertilizer treatments respectively whereas, SOF_0, SOF_1, SOF_2, SOF_3 and SOF_4 represent seed soaking with 10 ppm NAA without N-fertilizer, seed soaking with 10 ppm NAA with 25, 50, 75 and 100% of the recommended N-fertilizer respectively. On the other hand SSF_0 and SSF_1 indicate foliar application of 20 ppm NAA without N-fertilizer and 20 ppm NAA in combination with 25% of the recommended N-fertilizer respectively.

4.4.1 Effects of NAA and N-fertilizer on physiological parameters of timely and late sown BARI Gom-25

4.4.1.1 Plant height

Application of NAA at varying N-levels had resulted taller plant in timely and late sown BARI Gom-25 throughout the ages with significant variations (Table XVIIIa and XVIIIb).

Timely sown

At 30 DAS, significantly tallest plant was obtained from SOF_3 treatment which was 11.26 and 2.22% higher over the control and F_4 treatments respectively (Table XVIIIa). Significantly tallest plant at 45 DAS was recorded from SSF_1 treatment followed by SOF_3 and SOF_4 treatments respectively. Plant height recorded from SOF_3 treatment at 60 DAS-harvest were maximum and significantly higher than all other treatments except F_4 and SOF_4 treatments at 75 DAS. Plant height produced by SOF_2 and SSF_1 treatments at 75 DAS were also statistically identical to F_4, SOF_3 and SOF_4 treatments. At harvest, plant height due to F_4, SOF_3 and SOF_4 treatments increased by 4.25, 4.96 and 4.08% over control respectively.

Late sown

Height of BARI Gom-25 was also influenced positively by NAA treatments at varying N-levels where the tallest plant was found from SOF_3 treatment at all the ages except at 45 DAS (Table XVIIIb).

Table 4.XVIIIa. Effects of NAA and N-fertilizer on plant height (cm) of timely sown BARI Gom-25 at different ages during 2016-2017 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Control	32.23 g	43.34 f	64.24 f	79.37 e	82.43 e	82.54 e
F_4	35.08 bc	46.17 bc	68.01 a	82.06 ab	85.88 ab	86.05 ab
SOF_0	32.83 f	44.04 e	65.13 e	80.54 d	83.31 de	83.41 de
SOF_1	33.99 e	45.06 d	65.94 d	81.23 b-d	83.98 cd	84.07 cd
SOF_2	34.42 de	45.64 c	66.66 bc	81.96 a-c	84.78 bc	84.86 bc
SOF_3	35.86 a	46.41 b	68.52 a	82.52 a	86.57 a	86.64 a
SOF_4	35.25 b	46.23 b	68.09 a	82.19 a	85.78 ab	85.91 ab
SSF_0	33.03 f	44.62 d	66.07 cd	81.22 cd	82.91 de	82.93 de
SSF_1	34.63 cd	47.00 a	67.17 b	81.87 a-c	83.68 de	83.78 c-e
CV (%)	3.97	2.96	2.36	1.71	2.47	2.57
LSD (0.05)	0.59	0.55	0.63	0.83	1.27	1.41

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XVIIIb. Effects of NAA and N-fertilizer on plant height (cm) of late sown BARI Gom-25 at different ages during 2016-2017 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Control	33.00 d	44.10 f	65.16 f	80.09 f	83.16 d	82.53 f
F_4	35.64 a	46.68 b	68.43 a	82.62 b	86.32 b	86.58 a
SOF_0	33.49 c	44.87 e	66.04 e	81.35 e	84.19 c	84.22 de
SOF_1	35.13 b	45.81 d	66.59 cd	81.98 d	84.49 c	84.54 cd
SOF_2	34.93 b	45.98 cd	66.99 c	83.28 a	85.43 b	85.47 bc
SOF_3	36.01 a	46.78 b	68.58 a	83.16 a	87.38 a	86.99 a
SOF_4	35.67 a	46.43 bc	68.36 a	82.55 bc	85.98 b	86.03 ab
SSF_0	33.22 cd	45.03 e	66.33 de	82.09 cd	83.23 d	83.26 ef
SSF_1	34.86 b	47.31 a	67.53 b	82.91 ab	83.92 cd	83.95 de
CV(%)	3.50	2.51	1.94	1.39	2.06	2.21
LSD(0.05)	0.44	0.48	0.51	0.51	0.91	1.03

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

At 30-60 DAS, height of BARI Gom-25 due to SOF_3 treatment was significantly higher than all other treatments except F_4 and SOF_4 but at 45 DAS, the maximum was noted from SSF_1 treatment. Application of SOF_3 treatment produced tallest plant at 75 DAS but statistically not different from SOF_2 and SSF_1 treatments. At 90 DAS, significantly tallest plant (87.38 cm) was also noted from SOF_3 treatment. At harvest, the maximum increase in plant height due to SOF_3 was 5.40% over control and the minimum was 0.88% due to SSF_0.

4.4.1.2 Number of tillers per plant

Application of NAA in combination with different levels of N-fertilizer had significant responses on the number of tillers per plant of BARI Gom-25 (Table XIXa) and XIXb).

Timely sown

Results presented in Table XIXa revealed that SOF_3 treatment had resulted maximum number of tillers per plant throughout the growth periods where, it was significantly higher than most of the treatment but identical to F_4 and SOF_4 treatments with few exceptions. At 30-75 DAS, the least number of tillers per plant was noted from control and after that period the minimum value was observed from SOF_0 treatment but were statistically similar to those of control. Increases in number of tillers per plant due to SOF_3 treatment at 30, 45, 60, 75, 90 DAS and at harvest were 7.56, 1.78, 10.70, 3.75, 3.85 and 3.85% over the F_4 and 142.00, 161.71, 124.72, 136.99, 138.52 and 145.45% over control respectively.

Late sown

Number of tillers per plant were recorded maximum from SOF_3 treatment whereas, the minimum was found from control throughout the period (Table XIXb). Application of SOF_3 treatment had resulted significantly higher number of tillers per plant up to 75 DAS but after that period were statistically identical to F_4 and SOF_4 treatments. Number of tillers per plant due to SOF_3 treatment at 30, 45, 60, 75, 90 DAS and at harvest increased by 18.67, 16.75, 27.95, 12.00, 12.67 and 14.43% over F_4 and 167.00, 155.19, 90.06, 95.53, 95.03 and 97.60% over control respectively.

Table 4.XIXa. Effects of NAA and N-fertilizer on number of tillers per plant of timely sown BARI Gom-25 at different ages during 2016-2017 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Control	1.00 d	1.75 d	2.67 e	2.92 e	2.83 c	2.75 cd
F_4	2.25 a	4.50 a	5.42 b	6.67 a	6.50 a	6.50 a
SOF_0	1.17 cd	1.83 d	2.75 e	2.83 e	2.67 c	2.42 d
SOF_1	1.33 c	2.83 c	3.67 d	3.75 d	3.58 c	3.58 c
SOF_2	1.67 b	3.50 b	4.92 c	5.17 c	5.08 b	5.00 b
SOF_3	2.42 a	4.58 a	6.00 a	6.92 a	6.75 a	6.75 a
SOF_4	2.33 a	4.25 a	5.58 b	6.08 b	6.00 ab	6.00 ab
SSF_0	1.00 d	1.92 d	2.83 e	2.92 e	2.83 c	2.83 cd
SSF_1	1.25 cd	2.92 c	3.67 d	3.67 d	3.50 c	3.50 cd
CV(%)	12.62	17.87	12.56	16.87	13.76	18.00
LSD(0.05)	0.28	0.40	0.40	0.44	0.93	1.11

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XIXb. Effects of NAA and N-fertilizer on number of tillers per plant of late sown BARI Gom-25 at different ages during 2016-2017 season.

Treatments	Age of plant in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Control	1.00 e	1.83 e	3.42 e	3.58 d	3.42 d	3.33 c
F_4	2.25 b	4.00 b	5.08 c	6.25 b	5.92 ab	5.75 a
SOF_0	1.25 de	2.08 de	3.50 e	3.75 d	3.67 cd	3.50 c
SOF_1	1.42 d	3.00 c	3.67 e	4.00 d	3.83 cd	3.67 c
SOF_2	1.83 c	3.33 c	5.67 bc	6.00 b	5.58 b	5.42 b
SOF_3	2.67 a	4.67 a	6.50 a	7.00 a	6.67 a	6.58 a
SOF_4	2.25 b	3.92 b	5.75 b	6.00 b	5.75 ab	5.75 a
SSF_0	1.08 e	2.25 d	3.67 e	3.83 d	3.58 cd	3.58 c
SSF_1	1.50 d	3.17 c	4.33 d	4.92 c	4.50 c	4.42 bc
CV(%)	14.71	23.43	18.49	13.09	15.64	17.85
LSD(0.05)	0.28	0.40	0.59	0.69	1.03	1.09

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

4.4.1.3 Number of leaves per plant

Positive responses have been observed in the number of leaves per plant following different NAA treatments at varying N-levels in both the sowing time (Table XXa and XXb).

Timely sown

Number of leaves per plant was positively influenced by all treatments at all ages of growth except due to SSF_0 treatment of 45 DAS (Table XXa). The maximum number of leaves per plant was obtained from SOF_3 throughout the growth periods and were significantly higher than all other treatments at 75 and 90 DAS. At harvest, the highest increase in number of leaves per plant due to SOF_3 treatment was 115.44% over the control followed by F_4 (100.13%), SOF_4 (90.24%), SOF_2 (82.45%) treatments respectively.

Late sown

Application of NAA in combination with various doses of N-fertilizer had beneficial effects on the number of leaves per plant but with few exceptions (Table XXb). At 30 DAS, significantly maximum number of leaves per plant (9.42) was obtained from SOF_3 treatment although statistically not different from SOF_4 (8.83). Statistically similar number of leaves per plant was obtained from both F_4 (17.17) and SOF_3 (17.00) treatments at 45 DAS. At 60 DAS, maximum number of leaves (22.25) were recorded due to SOF_3 and was statistically at par with that of SOF_2. Number of leaves per plant at 90 DAS and at harvest were significantly higher than all other treatments including F_4. At harvest, number of leaves per plant increased by 10.82-103.13% over the control.

4.4.1.4 Total dry matter per plant

Application of NAA treatments in combination with different doses of N-fertilizer resulted higher dry matter per plant at both sowing time with few exceptions (Table XXIa and XXIb).

Timely sown

Significant variations in total dry matter (TDM) per plant were obtained among the treatments at all the ages (Table XXIa).

Table 4.XXa. Effects of NAA and N-fertilizer on number of leaves per plant of timely sown BARI Gom-25 at different ages during 2016-2017 season.

Treatments	Age of plant in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Control	3.17 d	7.92 d	11.92 d	9.25 f	7.83 e	7.58 d
F_4	9.00 a	18.83 a	23.83 a	23.00 b	16.17 b	15.17 ab
SOF_0	4.17 d	8.25 d	12.00 a	12.08	8.83 de	8.00 cd
SOF_1	5.50 bc	11.17 c	13.92 c	12.92 e	11.08 c	9.00 cd
SOF_2	6.50 b	13.42 b	20.50 b	19.58 c	15.00 b	13.83 b
SOF_3	10.00 a	17.83 a	24.17 a	25.42 a	19.67 a	16.33 a
SOF_4	9.50 a	14.92 b	21.67 b	22.67 b	16.58 b	14.42 b
SSF_0	3.50 d	7.58 d	13.66 c	11.83 e	9.33 c-e	8.33 cd
SSF_1	5.25 c	11.00 c	14.75 c	14.50 d	10.67 cd	9.42 c
CV(%)	14.88	15.65	11.08	14.34	15.41	14.47
LSD(0.05)	1.01	1.56	1.54	1.23	1.92	1.80

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XXb. Effects of NAA and N-fertilizer on number of leaves per plant of late sown BARI Gom-25 at different ages during 2016-2017 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Control	3.42 f	9.17 d	12.83 d	14.50 cd	9.50 e	7.67 f
F_4	8.17 b	17.17 a	20.50 b	22.92 a	14.92 b	14.25 b
SOF_0	4.25 e	8.75 de	12.67 d	12.75 e	9.25 e	8.50 ef
SOF_1	5.92 d	11.58 c	14.58 c	13.50 de	11.58 c	9.33 de
SOF_2	7.00 c	11.83 c	21.75 a	20.67 b	15.33 b	14.08 b
SOF_3	9.42 a	17.00 a	22.25 a	21.58 b	18.58 a	15.58 a
SOF_4	8.83 ab	14.25 b	20.25 b	21.17 b	15.50 b	13.33 bc
SSF_0	3.58 ef	8.00 e	11.67 d	12.33 e	10.08 de	8.83 ef
SSF_1	6.17 d	11.75 c	15.42 c	15.50 c	11.42 cd	10.25 cd
CV(%)	16.88	18.17	15.46	15.03	17.14	18.14
LSD(0.05)	0.77	1.03	1.23	1.21	1.37	1.25

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XXIa. Effects of NAA and N-fertilizer on total dry matter (g) per plant of timely sown BARI Gom-25 at different ages during 2016-2017 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Control	0.68 i	1.24 h	3.64 g	6.51 g	10.34 f	13.91 fg
F_4	1.59 b	3.39 b	7.86 b	13.06 b	17.97 b	21.30 bc
SOF_0	0.73 h	1.39 g	3.89 f	6.88 f	10.81 e	13.63 fg
SOF_1	1.08 f	1.67 e	4.17 e	7.86 e	11.05 e	14.89 ef
SOF_2	1.30 d	2.73 d	5.98 c	11.87 c	15.95 c	19.31 cd
SOF_3	1.76 a	3.81 a	9.07 a	16.47 a	19.98 a	26.59 a
SOF_4	1.47 c	3.21 c	7.94 b	13.19 b	18.15 b	22.99 b
SSF_0	0.84 g	1.29 h	3.04 h	6.42 g	9.73 g	11.86 g
SSF_1	1.17 e	1.51 f	5.04 d	8.96 d	13.76 d	17.62 de
CV(%)	13.38	23.60	17.13	13.96	16.27	22.11
LSD(0.05)	0.03	0.08	0.20	0.20	0.34	2.95

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XXIb. Effects of NAA and N-fertilizer on total dry matter (g) per plant of late sown BARI Gom-25 at different ages during 2016-2017 season.

Treatments	Age of plants in days after sowing (DAS)					At harvest
	30	45	60	75	90	
Control	0.69 f	1.29 gh	3.29 f	6.24 g	10.12 h	12.65 e
F_4	1.46 b	3.29 b	7.74 a	12.93 b	17.03 b	19.22 b
SOF_0	0.70 f	1.32 g	3.83 e	6.86 f	10.80 g	13.39 e
SOF_1	1.03 e	1.63 e	4.34 d	7.79 e	11.06 f	14.69 d
SOF_2	1.33 c	2.59 d	5.84 b	11.90 c	15.94 d	19.93 b
SOF_3	1.53 a	3.50 a	7.82 a	13.79 a	17.84 a	21.65 a
SOF_4	1.39 c	3.18 c	7.74 a	13.03 b	16.77 c	20.25 b
SSF_0	0.73 f	1.23 h	2.78 g	5.91 h	8.94 i	10.70 f
SSF_1	1.18 d	1.51 f	5.13 c	9.08 d	14.07 e	17.87 c
CV(%)	9.93	12.10	15.34	13.18	13.87	13.39
LSD(0.05)	0.06	0.08	0.20	0.20	0.20	1.09

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

The TDM per plant obtained from different treatments were higher than control but up to 60 DAS. After that period, positive influence was also noted by all treatments having an exception due to SSF_0 treatment. Application of SOF_3 treatment had resulted significantly higher TDM than all other treatments throughout the periods. Total dry matter per plant due to SOF_3 treatment at 30, 45, 60, 75 and 90 DAS and at harvest increased by 158.82, 207.26, 149.18, 152.99, 93.23 and 91.16% over the control and 10.69, 12.39, 15.39, 26.11, 11.19 and 24.84% over F_4 treatment respectively.

Late sown

At 30 DAS, total dry matter per plant was recorded maximum due to SOF_3 treatment which was significantly different from those of all other treatments (Table XXIb). The minimum was recorded from control and it was statistically at par to those of SOF_0 and SSF_0. At all other ages, higher amount of total dry matter per plant were recorded from all treatments except SSF_0. Significantly higher amount of TDM per plant was obtained from SOF_3 treatment all over the ages except at 60 DAS where, it was statistically at par to F_4 and SOF_4 treatments. Total dry matter per plant obtained from SOF_3 treatment were 4.79, 6.38, 1.03, 6.65, 4.76 and 12.64% higher over the control and 4.79, 6.38, 1.03, 6.65, 4.76 and 12.64% higher over F_4 treatments respectively.

4.4.2 Effects of NAA and N-fertilizer on yield attributes and yield of timely and late sown BARI Gom-25

Yield attributes and yield of BARI Gom-25 responded positively following most of the treatments with both significant and non-significant variations in both sowing time (Table XXIIa and XXIIb).

4.4.2.1 Number of effective tillers (spikes) per plant

Timely sown

Number of effective tillers per plant was increased following all treatments except SOF_0 (Table XXIIa). The maximum number of effective tillers per plant (6.67) was obtained from SOF_3 although statistically similar to F_4 (6.33) and SOF_4 (5.75) treatments but significantly different from rest of the treatments.

Late sown

Application of NAA in combination with various doses of nitrogen fertilizer had stimulatory effect on number of effective tillers per plant (Table XXIIb). Significantly higher number of effective tillers per plant (6.50) was observed from SOF_3 treatment but was statistically at par to F_4 (5.58), SOF_2 (5.25) and SOF_4 (5.58) treatments.

4.4.2.2 Number of non-effective tillers per plant

Timely sown

Number of non-effective tillers per plant was reduced following all treatments but with non-significant variations. However, similar number (0.25) was produced by both control and SOF_4 treatments (Table XXIIa). The lowest number of non-effective tillers per plant (0.08) was recorded from SOF_0, SOF_1, SOF_2 and SOF_3 treatments.

Late sown

Non-effective tillers per plant were affected non-significantly. Both increase and decrease in number of non-effective tillers per plant were observed due to different treatments (Table XXIIb). The minimum number of non-effective tillers per plant (0.08) was noted from SOF_1 and SOF_3 treatments whereas, SSF_0 treatment had maximum value (0.33).

4.4.2.3 Length of spike

Timely sown

Application of NAA at varying N-levels resulted non-significantly longer length of spike (Table XXIIa). The maximum increase due to SOF_3 was 6.06% over the control followed by SOF_4 (5.52%) and F_4 (5.19%) treatments respectively, whereas, the minimum was 0.54% due to SSF_0 treatment.

Late sown

Significant variations in length of spike was obtained in late sown wheat. Length of spike was influenced positively following NAA in combination with N-fertilizer treatments (Table XXIIb). The maximum length of spike (9.83) was obtained from SOF_3 treatment which was 5.59% higher over the control.

Table 4.XXIIa. Effects of NAA and N-fertilizer on yield attributes and yield of timely sown BARI Gom-25 at harvest during 2016-2017 season.

Treatments	No. of effective tillers/ plant	No. of non-effective tillers/ plant	Length of spike (cm)	Dry weight of spikes (g)	No. of grains/ spike	No. of grains/ plant	1000-grain weight (g)	Yield/ plant (g)	Yield/ Ha (t)	HI (%)
Control	2.50 cd	0.25	9.24	9.16 ef	27.18 c-e	67.42 e	43.82 d	3.05 e	1.52 e	21.75 b
F_4	6.33 a	0.17	9.72	14.01 bc	25.97 de	158.36 b	45.33 b	6.21 bc	3.10 bc	28.81 a
SOF_0	2.33 d	0.08	9.45	8.95 f	33.42 ab	77.05 de	44.16 d	2.68 e	1.34 e	19.50 b
SOF_1	3.50 c	0.08	9.60	9.77 ef	31.53 ab	107.08 cd	44.92 c	4.83 d	2.42 d	33.13 a
SOF_2	4.92 b	0.08	9.61	12.36 cd	31.90 ab	156.35 b	45.37 b	6.63 a-c	3.31 a-c	34.22 a
SOF_3	6.67 a	0.08	9.80	16.54 a	29.74 b-d	198.08 a	45.80 a	7.75 a	3.88 a	30.15 a
SOF_4	5.75 ab	0.25	9.75	15.16 ab	30.63 a-c	175.29 ab	45.19 bc	7.44 ab	3.72 ab	33.13 a
SSF_0	2.67 cd	0.17	9.29	7.78 f	24.86 e	64.21 e	43.97 d	2.72 e	1.36 e	22.58 b
SSF_1	3.33 cd	0.17	9.65	11.13 de	34.16 a	112.33 c	45.83 a	5.77 cd	2.88 cd	32.32 a
CV (%)	18.71	28.91	8.36	12.08	8.20	18.62	1.88	4.71	4.71	12.13
LSD (0.05)	1.09	NS	NS	2.04	3.94	32.55	0.34	1.29	0.65	6.12

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XXIIb. Effects of NAA and N-fertilizer on yield attributes and yield of late sown BARI Gom-25 at harvest during 2016-2017 season.

Treatments	No. of effective tillers/ plant	No. of non-effective tillers/ plant	Length of spike cm)	Dry weight of spikes (g)	No. of grains/ spike	No. of grains/ plant	1000-grain weight (g)	Yield/ plant (g)	Yield/ Ha (t)	HI (%)
Control	3.17 c	0.17	9.31 b	8.84 d	26.91 a	84.17 d	43.69 e	3.49 d	1.75 d	28.44 bc
F_4	5.58 ab	0.17	9.67 ab	13.13 ab	30.09 ab	164.34 b	45.15 bc	6.29 a-c	3.15 a-c	33.02 ab
SOF_0	3.33 c	0.17	9.47 ab	10.73 cd	25.81 c	87.84 d	44.08 d	3.84 d	1.92 d	25.45 c
SOF_1	3.58 c	0.08	9.42 ab	10.27 cd	27.03 bc	96.83 d	45.00 c	5.31 c	2.65 c	32.91 ab
SOF_2	5.25 b	0.17	9.46 ab	13.71 ab	29.55 a-c	143.32 bc	45.26 bc	6.35 a-c	3.18 a-c	31.10 a-c
SOF_3	6.50 a	0.08	9.83 a	14.73 a	32.27 a	205.33 a	45.67 a	7.50 a	3.75 a	35.95 a
SOF_4	5.58 ab	0.17	9.75 ab	13.93 ab	30.44 ab	167.87 b	45.34 b	7.01 ab	3.51 ab	34.87 a
SSF_0	3.25 c	0.33	9.33 b	6.50 e	29.63 a-c	93.67 d	43.78 e	3.75 d	1.88 d	34.84 a
SSF_1	4.17 c	0.25	9.67 ab	11.83 bc	32.01 a	130.15 c	45.38 b	5.81 bc	2.90 bc	32.14 ab
CV (%)	18.32	8.34	6.42	31.04	17.85	9.36	1.79	39.16	39.16	23.67
LSD (0.05)	1.03	NS	0.48	2.14	3.92	26.20	0.28	1.41	0.69	5.88

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

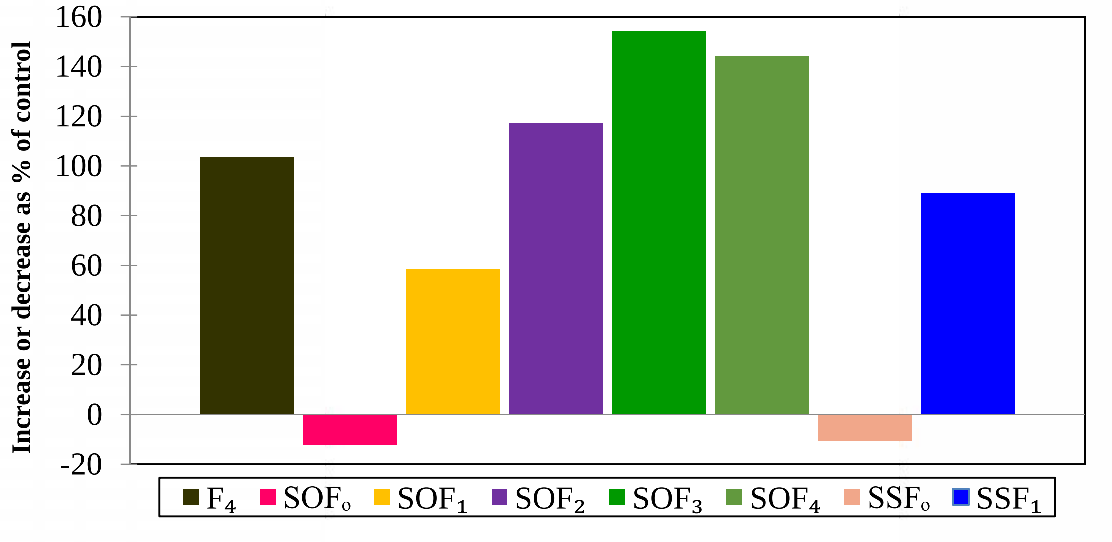

Fig. 4.3a. Yield per plant of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer during 2016-2017 season.

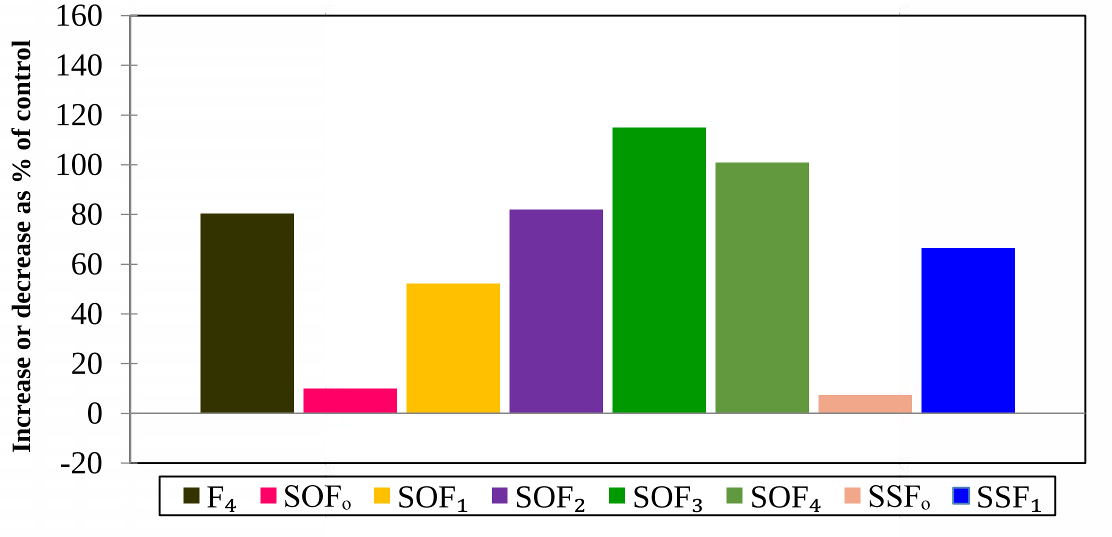

Fig. 4.3b. Yield per plant of late sown BARI Gom-25 as influenced by NAA and N-fertilizer on during 2016-2017 season.

4.4.2.4 Dry weight of spike

Dry weight of spike was significantly affected in both timely and late sown wheat.

Timely sown

Dry weight of spikes was positively influenced by different NAA treatments with few exceptions (Table XXIIa). Higher values in dry weight of spike were observed from F_4, SOF_1, SOF_2, SOF_3, SOF_4 and SSF_1 treatments. Maximum dry weight of spike was obtained from SOF_3 and it was significantly different from all other treatments except that of SOF_4. Dry weight of spike due to SOF_3 was 80.57% higher over control followed by SOF_4 (65.50%) and F_4 (52.94%) treatments respectively.

Late sown

Application of NAA at varying N-levels had stimulatory effect on dry weight of spike except due to SSF_0 treatment (Table XXIIb). The maximum value in dry weight of spike (14.73 g) was recorded from SOF_3 treatment and was statistically identical to F_4, SOF_2 and SOF_4 but significantly different from rest of the treatments. Dry weight of spike due to F_4, SOF_0, SOF_1, SOF_2, SOF_3, SOF_4 and SSF_1 treatments were 48.53, 21.38, 16.18, 55.09, 66.63 and 33.82% higher over the control.

4.4.2.5 Number of grains per spike and per plant

Timely sown

Different NAA treatments at various N-levels had significant responses on number of grains per spike and plant (Table XXIIa). The maximum number of grains per spike (34.16) was recorded from SSF_1 treatment which was significantly higher than all other treatments except SOF_0, SOF_1, SOF_2 and SOF_0. In case of number of grains per plant, significantly maximum number of grains per plant was noted from SOF_3 and was statistically identical to SOF_4 treatment. Number of grains per plant produced by SOF_3 was 25.08% higher over F_4 treatment whereas 193.80% higher over control.

Late sown

Application of NAA in combination with various doses of nitrogen fertilizer had beneficial effect on number of grains per spike and grains per plant except due to SOF_0 treatment in case of number of grains per spike (Table XXIIb). Number of grains per spike obtained from SOF_3 (32.27) although significantly higher than SOF_0 and SOF_1 but statistically identical to rest of the treatments. Significantly highest number of grains per plant (205.33) was also recorded from SOF_3 treatment and was 143.55 and 24.94% higher over control and F_4 treatments respectively.

4.4.2.6 1000-grain weight

In both timely and late sown wheat, 1000-grain weight influenced significantly.

Timely sown

Weight of 1000-grain was increased due to application of all treatments (Table XXIIa). Significantly maximum 1000-grain weight (45.83 g) was obtained from SSF_1 treatment which was statistically similar to SOF_3 (45.80 g). Weight of 1000-grain due to SOF_3 and SSF_1 treatments was 4.52 and 4.59% higher over the control.

Late sown

Weight of 1000-grain due to various treatments was recorded higher than control (Table XXIIb). Significantly maximum 1000-grain weight (45.67 g) was noted from SOF_3 followed by SSF_1 (45.38 g) and SOF_4 (45.34 g) treatments respectively. The maximum increase due to SSF_3 treatment was 4.53 and 1.15% over control and F_4 treatments respectively.

4.4.2.7 Yield per plant and per hectare

Timely sown

Yield per plant and per hectare of BARI Gom-25 was significantly influenced by most of the treatments (Table XXIIa). The maximum yield per plant (7.75 g) and per hectare (3.88 t) was obtained from SOF_3 treatment followed by SOF_4, SOF_2, F_4 and SSF_1 treatments respectively. The minimum yield per plant and per hectare were recorded from SOF_0 preceded by SSF_0 treatment and these were statistically similar to control. Yield per plant obtained from F_4, SOF_1, SOF_2, SOF_3, SOF_4 and SSF_1

treatments were 103.61, 58.36, 117.38, 154.10, 143.93 and 89.18% higher over the control respectively. The maximum increase in yield per plant due to SOF_3 was 24.80% over F_4 treatment (Fig. 4.3a).

Late sown

Higher values in yield per plant and per hectare were recorded from different NAA treatments with significant variations (Table XXIIb). Yield per plant (7.50 g) and per hectare (3.75 t) were also recorded maximum from SOF_3 treatment followed by SOF_4, SOF_2, F_4 and SSF_1 treatments respectively. Increase in yield per plant due F_4, SOF_1, SOF_2, SOF_3, SOF_4 and SSF_1 treatments were 80.23, 52.15, 81.95, 114.90, 100.86 and 66.48% over the control respectively. Yield per plant due to SOF_3 treatment increased by 19.24% over F_4 treatment (Fig. 4.3a).

4.4.2.8 Harvest index

Significant variations in harvest index were obtained in both timely and late sown wheat.

Timely sown

Harvest index (HI) was increased following the application of NAA in combination with various doses of N-fertilizer but with an exception due to SOF_0 (Table XXIIa). The maximum HI was noted from SOF_2 (34.22%) followed by SOF_1 and SOF_4 (33.13%), SSF_1 (32.32%) and F_4 (28.81%) respectively.

Late sown

Harvest index of BARI Gom-25 was positively influenced by most of the treatments (Table XXIIb). The highest HI (35.95%) was observed from SOF_3 followed by SOF_4 (34.87%), SSF_0 (34.84%) and F_4 (33.02%) treatments respectively.

4.4.3 Effects of NAA and N-fertilizer on biochemical parameters of timely and late sown BARI Gom-25

Biochemical parameters *viz.* pigment content of leaves, NPK contents, NPK uptake and nitrogen use efficiency (NUE) of shoot, root and grain were determined at different stages of growth in both timely and late sown condition. Considering yield performances, three treatments of timely sown BARI Gom-25 were selected for comparative analysis on some nutritional parameters, amino acids profile, enzyme activities and minerals content of grains.

4.4.3.1 Pigment contents of leaves

Pigment contents of leaves at three different stages *viz*. tillering, flowering and grain filling were remarkably influenced by different treatments at both timely and late sown condition (Table XXIIIa, XXIIIb and XXIIIc).

At tillering stage

Timely sown

Application of NAA in combination with various N-levels resulted significantly higher amount of pigments than control where the maximum was noted from SOF_4 followed by SOF_3 treatment except in case of carotenoids (Table XXIIIa). Here, chl. a, chl. b and carotenoids contents due to SOF_4 treatment were 50.0, 20.93 and 9.53% higher over F_4 treatment.

Late sown

Application of NAA at varying N-levels had beneficial effects on pigment contents of leaves (Table XXIIIa). The maximum value in chl. a and chl.b was recorded from SOF_4 treatment followed by SOF_3. However, the highest amount of carotenoids was found from SOF_3 treatment. Chl. a, chl. b and carotenoids contents due to SOF_4 treatment increased by 36.36, 20.51 and 42.93% over F_4 treatment.

At flowering stage

Timely sown

Pigment contents *viz.* chl. a and carotenoids content of leaves were increased following all treatments where, significantly highest amount was obtained from SOF_4 treatment (Table XXIIIb). Application of SOF_4 treatment also produced significantly higher chl. b content of leaves although other treatments had produced lower amount in comparison to control. The maximum increase in chl. a, chl. b and carotenoids due to SOF_4 treatments were 80.77, 108.33 and 38.58% over F_4 treatment.

Table 4.XXIIIa. Effects of NAA and N-fertilizer on pigment contents (mg/g) of leaves of timely and late sown BARI Gom-25 at tillering stage during 2016-2017 season.

Treatments	Timely sown			Late sown		
	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids
Control	0.09 i	0.23 f	3.00 i	0.12 h	0.23 g	3.00 i
F_4	0.66 c	0.43 c	4.93 e	0.66 c	0.39 c	4.10 g
SOF_0	0.11h	0.37 de	3.65 h	0.13 h	0.37 de	3.84 h
SOF_1	0.42 f	0.38 de	4.35 g	0.39 f	0.38 cd	4.28 f
SOF_2	0.48 e	0.38 de	4.98 d	0.45 e	0.35 f	5.08 d
SOF_3	0.96 b	0.47 b	5.05 c	0.88 b	0.46 a	5.91 a
SOF_4	0.99 a	0.52 a	5.40 a	0.90 a	0.47 a	5.86 b
SSF_0	0.20 g	0.35 e	5.10 b	0.23 g	0.36 ef	5.28 c
SSF_1	0.57 d	0.39 d	4.56 f	0.58 d	0.41 b	4.60 e
CV (%)	13.83	19.96	16.26	18.13	17.72	19.65
LSD (0.05)	0.01	0.03	0.04	0.01	0.01	0.02

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XXIIIb. Effects of NAA and N-fertilizer on pigment contents (mg/g) of leaves of timely and late sown BARI Gom-25 at flowering stage during 2016-2017 season.

Treatments	Timely sown			Late sown		
	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids
Control	0.13 g	0.44 b	4.27 f	0.17 g	0.29 a	2.69 f
F_4	0.78 de	0.24 c	5.91 e	0.69 a	0.20 c	4.33 c
SOF_0	0.15 g	0.18 d	5.79 e	0.46 d	0.13 de	3.95 d
SOF_1	0.75 e	0.24 c	6.42 d	0.39 e	0.11 ef	4.09 d
SOF_2	0.50 f	0.18 d	5.81 e	0.63 b	0.14 d	4.70 b
SOF_3	1.26 b	0.41 b	7.75 b	0.56 c	0.13 de	5.06 a
SOF_4	1.41 a	0.50 a	8.19 a	0.70 a	0.23 b	4.42 c
SSF_0	0.81 d	0.27 c	7.02 c	0.26 f	0.04 g	2.77 f
SSF_1	0.97 c	0.04 e	8.12 a	0.44 d	0.10 f	3.35 e
CV (%)	16.19	12.10	18.97	16.88	18.61	20.46
LSD (0.05)	0.03	0.04	0.21	0.02	0.02	0.15

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Late sown

Application of NAA in combination with various doses of N-fertilizer had resulted higher amount of chl.a and carotenoids contents with significant variations however, the response was negative in case of chl. b content. Significantly higher chl. a (0.70 mg/g) and carotenoids (5.06 mg/g) contents were observed from SOF_4 and SOF_3 treatments respectively (Table XXIIIb).

At grain filling stage

Timely sown

Results indicated in Table XXIIIc revealed that most of the treatments had inducing effects on pigment contents of leaves. Significantly maximum chl. a content (1.27 mg/g) was noted from SOF_4 treatment whereas, maximum chl. b (0.85 mg/g) and carotenoids (8.86 mg/g) were noted from SOF_3 treatment.

Late sown

Positive stimulation in pigment contents of leaves were obtained from all treatments where, the maximum quantity was obtained from SOF_4 treatment with significant variations although carotenoids content was statistically at par to SSF_0 (Table XXIIIc). Chl. a and chl. b contents recorded from SOF_4 treatment were 58.93 and 93.33% higher over F_4 treatment. Carotenoids content increased by 42.65% over F_4 treatment.

4.4.3.2 NPK contents and uptake by shoot, root and grain

4.4.3.2.1 NPK contents of shoot, root and grain

Application of NAA in combination with various nitrogen levels had both stimulatory and retarding effects on NPK contents of shoot, root and grain of BARI Gom-25 where both significant and non-significant variations were observed at different stages (Table XXIVa, XXIVb and XXIVc).

Table 4.XXIIIc. Effects of NAA and N-fertilizer on pigment contents (mg/g) of leaves of timely and late sown BARI Gom-25 at grain filling stage during 2016 2017 season.

Treatments	Timely sown			Late sown		
	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids
Control	0.69 g	0.24 g	8.71 bc	0.27 h	0.06 h	4.41 g
F_4	0.85 e	0.42 c	6.78 ab	0.56 e	0.15 f	4.90 e
SOF_0	0.76 f	0.38 d	8.62 c	0.29 g	0.09 g	4.80 f
SOF_1	0.75 f	0.21 h	6.56 e	0.50 f	0.17 e	4.41 g
SOF_2	1.16 b	0.34 e	8.79 ab	0.67 c	0.23 c	5.55 c
SOF_3	1.04 c	0.85 a	8.86 a	0.85 b	0.26 b	6.59 b
SOF_4	1.27 a	0.30 f	8.72 bc	0.89 a	0.29 a	6.99 a
SSF_0	0.64 h	0.29 f	6.48 e	0.62 d	0.19 d	6.98 a
SSF_1	0.93 d	0.59 b	6.77 d	0.62 d	0.17 e	5.33 d
CV (%)	13.08	17.84	13.55	14.78	14.43	17.97
LSD (0.05)	0.02	0.01	0.12	0.01	0.01	0.02

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

At flowering stage

Timely sown

The NPK contents of shoot were increased significantly following all treatments (Table XXIVa). Significantly maximum (1.49%) N content was obtained from SOF_4 treatment which was 93.51% higher over the control followed by SOF_3 (81.82%), SOF_2 (70.13%) and SOF_1 (35.06%) treatments respectively. The highest content of P (0.75%) and K (2.76%) were recorded from SOF_2 treatment where it was significantly higher than rest of the treatments. The P content increased by 15.79-97.37% over the control whereas in case of K, it was varied from 21.14-124.39%.

Positive influences on NPK contents of root has been observed following different treatments but with few exceptions (Table XXIVa). The maximum N content (1.22%) of root was obtained from SSF_1 treatment which was significantly higher than the other treatments. Significantly higher P content of root was recorded from both SOF_0 and SOF_1 (0.60%) treatments followed by SOF_2 (0.57%), SSF_0 (0.56%) and SSF_1 (0.55%) respectively. Application of different treatments had resulted 3.33-50.0% higher K content in root than control although, F_4 and SOF_3 treatments reduced it significantly.

Late Sown

The NPK contents of shoot were responded positively following all treatments with significant variations (Table XXIVa). Increases in NPK contents due to various treatments were ranged from 11.94-102.99, 26.67-156.67, 17.42-121.97% over the control respectively.

Different treatments had resulted significantly higher N content in root where the maximum increase due to SSF_1 was 100% over the control. In case of P content in root, significantly higher value (0.54%) was noted from SOF_0 treatment whereas, the minimum was obtained from F_4 (0.39%). The K content of root was influenced similarly like P content where, the maximum increase due to SOF_1 treatment was 50.51% over the control followed by SSF_0 (36.36%), SOF_0 (26.26%), SOF_2 (18.18%) respectively.

Table 4.XXIVa. Effects of NAA and N-fertilizer on NPK contents (%) of shoot and root of timely and late sown BARI Gom-25 at flowering stage during 2016 2017 season.

Treatments	Timely sown						Late sown					
	Shoot			Root			Shoot			Root		
	N	P	K	N	P	K (%)	N	P	K	N	P	K
Control	0.77 h	0.38 g	1.23 h	0.68 h	0.53 c	0.90 g	0.67 h	0.30 e	1.32 h	0.59 e	0.42d	0.99f
F_4	0.95 e	0.47 e	2.08 e	1.00 c	0.39 e	0.74 i	0.87 e	0.38 d	2.20 e	0.79 c	0.39e	0.78h
SOF_0	0.86 g	0.58 c	2.44 b	0.77 g	0.60 a	1.15 c	0.75 g	0.49 c	2.55b	0.69d	0.54a	1.25c
SOF_1	1.04 d	0.51 d	1.49 g	0.86 e	0.60 a	1.35 a	0.97d	0.46 c	1.55 g	0.79 c	0.50b	1.49a
SOF_2	1.31 c	0.75 a	2.76 a	0.95 d	0.57 b	0.98 e	1.23 c	0.77 a	2.93 a	0.90b	0.47c	1.17d
SOF_3	1.40 b	0.61 b	2.07 e	1.04 b	0.49 d	0.85 h	1.29b	0.57 b	2.21 e	0.91b	0.42d	0.88g
SOF_4	1.49 a	0.44 f	1.91 f	0.63 i	0.47 d	0.93 f	1.36 a	0.36 d	2.11 f	0.59 e	0.40de	1.09e
SSF_0	0.91 f	0.59 bc	2.33 c	0.81 f	0.56 b	1.25 b	0.80 f	0.47 c	2.44 c	0.78 c	0.50b	1.35b
SSF_1	0.95 e	0.51 d	2.25 d	1.22 a	0.55 b	1.09 d	0.88 e	0.46 c	2.37d	1.18 a	0.49bc	1.11e
CV (%)	12.99	19.66	12.85	10.23	12.35	18.51	14.56	17.86	11.51	11.88	11.61	18.86
LSD (0.05)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

At grain filling stage

Timely sown

Affirmative effects of different treatments has been observed in N content of shoot except F_4 and increased by 12.50-126.39% over control (Table XXIVb). Positive influence of various treatments was also noticed in case of P content in shoot where significantly highest amount (0.58%) was obtained from F_4 treatment however, the minimum (0.27%) was noted from SSF_0 treatment. Higher values of K content were recorded from majority of treatments where the maximum increase due to SOF_2 was 27.22% higher over control followed by SOF_3 (24.61%) and F_4 (23.56%) treatments respectively.

Increase as well as decrease in NPK contents of root were observed from different treatments. Significantly higher N content of root was recorded from F_4 (0.86%) followed by SOF_4 (0.81%) and SOF_3 (0.77%) treatments respectively whereas, rest of the treatments resulted significantly lower values than control. The maximum P content (0.61%) of root was found from both SOF_1 and SOF_3 treatments but were significantly higher than all other treatments. The K content of root was recorded maximum from SSF_0 (1.25%) which was statistically at par with SOF_3 (1.23%) but significantly different from rest of the treatments.

Late sown

Both increase and decrease in NPK contents of shoot and root were recorded from different treatments except N content of shoot (Table XXIVb). Application of NAA at varying N-levels produced 1.64-150.82% higher N content of shoot over the control. Significantly higher P content of shoot were obtained from F_4, SOF_0, SOF_3 and SOF_4 treatments whereas rest of the treatments had negative responses with both significant and non-significant variations. The lowest K content of shoot although obtained from SSF_0 treatment but, rest of the treatments resulted 3.96-20.59% higher value than control with significant variations.

Application of F_4 treatment produced maximum N content of root (0.75%) although statistically identical to SOF_4 but significantly higher than rest of the treatments. The maximum P content (0.57%) of root was noted from SOF_3 followed by SOF_1 (0.56%) and SOF_2 (0.48%) treatments respectively however, negative influences

Table 4.XXIVb. Effects of NAA and N-fertilizer on NPK contents (%) of shoot and root of timely and late sown BARI Gom-25 at grain filling stage during 2016 2017 season.

Treatments	Timely sown						Late sown					
	Shoot			Root			Shoot			Root		
	N	P	K	N	P	K (%)	N	P	K	N	P	K
Control	0.72 g	0.45 e	1.91 g	0.63 d	0.51 b	0.97 d	0.61 f	0.37c	2.02f	0.57c	0.44d	1.10b
F_4	0.68 h	0.58 a	2.36 b	0.86 a	0.52 b	1.09 b	0.62 f	0.49a	2.40b	0.78a	0.45cd	1.12b
SOF_0	0.81 f	0.48 cd	2.07 f	0.54 e	0.45 c	0.92 e	0.75 e	0.41b	2.10e	0.46d	0.41e	0.98cd
SOF_1	1.49 b	0.42 f	2.12 e	0.54 e	0.61 a	0.96 d	1.39 b	0.38bc	2.24d	0.46d	0.56a	1.22a
SOF_2	0.91 e	0.42 f	2.43 a	0.50 e	0.51 b	0.93 e	0.84 d	0.37c	2.40b	0.43d	0.48b	0.96de
SOF_3	1.40 c	0.54 b	2.38 b	0.77 c	0.61 a	1.23 a	1.37 b	0.48a	2.44a	0.67b	0.57a	1.24a
SOF_4	1.63 a	0.49 c	2.20 d	0.81 b	0.54 b	1.04 c	1.53 a	0.41b	2.37b	0.75a	0.47bc	1.13b
SSF_0	0.91 e	0.27 g	1.29 h	0.54 e	0.44 c	1.25 a	0.87 d	0.23d	1.30g	0.44d	0.38f	0.93e
SSF_1	1.22 d	0.46 de	2.23 c	0.54 e	0.45 c	0.97 d	1.19 c	0.40bc	2.30c	0.46d	0.37f	1.00c
CV (%)	13.43	18.98	15.84	10.91	12.71	11.53	13.23	19.25	15.50	14.28	15.30	10.26
LSD (0.05)	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.03

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

were also observed from SOF_0, SSF_0 and SSF_1 treatments. Increase in K content due to F_4, SOF_1, SOF_3 and SOF_4 were 1.82, 10.91, 12.73 and 2.73% higher over the control however, K content decreased by 9.09-15.45 following SOF_0, SOF_2 SSF_0 and SSF_1 treatments.

At harvest

Timely sown

The NPK contents of shoot and root were both positively and negatively responded by different treatments where treatment means varied both significant and non-significant responses (Table XXIVc). The N content of shoot was recorded higher following all treatments with significant variations however, only decrease was noted from SSF_0 treatment (0.32%) which was significantly lower than other treatments. Significantly higher P content of shoot was noted from SOF_4 (0.21%), SOF_1 (0.20%), SOF_3 (0.19%) and F_4 (0.19%) treatments whereas other treatments produced lower amount of P content but statistically at par to control. Application of SOF_1, SOF_3, SOF_4 and SSF_1 treatments had resulted 3.95, 10.53, 30.26 and 28.29% higher K content over control respectively however, K content decreased by 1.97-8.55% following rest of the treatments with significant variations.

Both increase and decrease in N content of root were obtained from different treatments where the maximum increase (18.18%) and decrease (23.38%) was noted from SOF_2 and SSF_1 treatments respectively. Positive influences in P content of root was observed from SOF_0, SOF_1, SOF_3 and SSF_0 treatments where significantly higher content was recorded from SSF_0 treatment. In this case, F_4 treatment produce least amount which was significantly lower than all other treatments except SSF_1. Different treatment had inhibitory effect on K content of root where the maximum decrease due to SOF_4 was 50.67% than control. The NPK contents of grain were recorded higher following all treatments except due to SSF_0 and SSF_1 in case of K. The maximum increase in N, P and K contents were 16.80, 8.33 and 23.33% over the control respectively.

Late sown

Both increase and decrease in N and P contents of shoot were recorded from various treatments (Table XXIVc).

Table 4.XXIVc. Effects of NAA and N-fertilizer on NPK contents (%) of shoot, root and grain of timely and late sown BARI Gom-25 at harvest during 2016 2017 season.

Treatments	Timely sown									Late sown								
	Shoot			Root			Grain			Shoot			Root			Grain		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
	(%)																	
Control	0.36 f	0.14 bc	1.52 e	0.77 c	0.29 c	0.75 a	2.44 f	0.36 c	0.30 b	0.23c	0.09a-c	2.44a	0.59d	0.04g	1.08 d	2.32 g	0.35 c	0.26 d
F_4	0.50 c	0.19 a	1.49 f	0.81 b	0.23 e	0.56 c	2.78 b	0.39 a	0.36 a	0.27b	0.10 ab	1.18g	0.86a	0.23b	1.03 e	2.72 b	0.38 a	0.37 a
SOF_0	0.41 e	0.12 c	1.39 g	0.68 e	0.30 c	0.68 b	2.45 f	0.37 bc	0.32 b	0.18d	0.10 ab	1.27f	0.50e	0.18de	1.14 c	2.32 g	0.36 bc	0.33 b
SOF_1	0.50 c	0.20 a	1.58 d	0.77 c	0.30 c	0.68 b	2.52 e	0.37 bc	0.37 a	0.27b	0.11 a	1.38e	0.72c	0.19cd	0.98 f	2.52 e	0.37 ab	0.37 a
SOF_2	0.50 c	0.14 bc	1.49 f	0.91 a	0.27 cd	0.42 e	2.62 d	0.37 bc	0.37 a	0.36a	0.08 bc	1.52d	0.72c	0.18de	0.74 g	2.62 c	0.38 a	0.38 a
SOF_3	0.54 b	0.19 a	1.68 c	0.77 c	0.35 b	0.45 d	2.85 a	0.38 ab	0.37 a	0.29b	0.09a-c	1.84c	0.72c	0.06f	0.62 h	2.84 a	0.38 a	0.38 a
SOF_4	0.59 a	0.21 a	1.98 a	0.72 d	0.28 c	0.37 f	2.72 c	0.38 ab	0.36 a	0.34a	0.07c	1.90b	0.81b	0.20c	0.51 i	2.71 b	0.38 a	0.37 a
SSF_0	0.32 g	0.15 b	1.39 g	0.77 c	0.50 a	0.66 b	2.51 e	0.37 bc	0.25 c	0.18d	0.11 a	1.15h	0.50e	0.25a	2.12 a	2.45 f	0.37 ab	0.27 d
SSF_1	0.45 d	0.16 b	1.95 b	0.59 f	0.25 de	0.38 f	2.60 d	0.37 bc	0.30 b	0.18d	0.10 ab	0.63 i	0.72c	0.17e	1.37 b	2.58 d	0.36 bc	0.31 c
CV (%)	18.12	9.70	13.23	11.40	15.41	15.65	5.37	3.17	12.60	16.19	18.83	13.84	17.48	14.02	12.91	6.73	3.35	13.27
LSD(0.05)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.01

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

The highest N content was found from SOF_2 (0.36%) although statistically similar to SOF_4 (0.34%) but significantly different from rest of the treatments. The lowest N content of shoot (0.18%) was obtained from SOF_0, SSF_0 and SSF_1 treatments and was significantly different from other treatments. The P content of shoot varied from 0.70-0.11% with insignificant variations. The K content of shoot decreased up to 74.18% due to different treatments. with significant variations. Increases in N content of root due to F_4, SOF_1, SOF_2, SOF_3 SOF_4 and SSF_1 treatments were 22.03-45.76% over the control however, N content decreased by 15.25% due to both SOF_0 and SSF_0 treatments. Application of different treatments produced higher P content of root where SSF_0 treatment had significantly maximum content (0.25%). Significantly higher K content of root was obtained from SOF_0, SSF_0 and SSF_1 treatments whereas, rest of the treatments reduced it with significant variations. The NPK contents of grain remarkably increased following all treatments with both significant and non-significant variations. The maximum increase in N, P and K contents was 22.41, 8.57 and 46.15% over the control respectively.

4.4.3.2.2 NPK uptake by shoot, root and grain

The NPK uptake by shoot and root at flowering and grain filling stages and shoot, root and grain at harvest were positively stimulated by most of the treatments in both the sowing condition. In this cases, treatment means were varied with both significant and non-significant responses. (Table XXVa, XXVb and XXVc).

At flowering stage

Timely sown

The NPK uptake by shoot and root increased due to all treatments except N-uptake by shoot where, only decrease was noted from SOF_0 treatment (Table XXVa). The maximum N-uptake (138.16 mg/g) was obtained from SOF_4 treatnment followed by SOF_3 (163.16 mg/g), SOF_2 (113.13 mg/g) and F_4 (94.56 mg/g) treatments respectively. Significantly maximum P and K uptake by shoot and NPK uptake by root were obtained from SOF_3 treatment although it was statistically at par to SOF_2 treatment in case of P uptake by root. Results revealed that SOF_2, SOF_3 and SOF_4 treatments had significantly higher NPK uptake by shoot and root than F_4 treatment in

Table 4.XXVa. Effects of NAA and N-fertilizer on NPK uptake (mg/g) by shoot and root of timely and late sown BARI Gom-25 at flowering stage during 2016-2017 season.

Treatments	Timely sown						Late sown					
	Shoot			Root			Shoot			Root		
	N	P	K	N	P	K (mg/g)	N	P	K	N	P	K
Control	40.39 h	19.82 h	64.48 i	3.26 f	2.53 e	4.32 g	33.47 h	14.69 i	65.79 i	2.59 g	1.87 f	4.35 h
F_4	94.56 d	46.90 d	206.64 d	7.67 c	2.99 d	5.73 f	84.20 d	36.67 d	212.92 d	5.68 c	2.77 d	5.62 g
SOF_0	39.98 i	27.19 g	113.44 f	4.31 e	3.38 cc	6.44 e	33.53 h	21.81 g	114.16 f	3.72 f	2.93 d	6.75 e
SOF_1	72.76 f	35.72 f	103.83 h	5.07 d	3.51 c	7.94 c	65.14 f	30.85 f	104.29 h	4.47 e	2.86 d	8.50 c
SOF_2	113.13 c	64.28 b	238.05 b	9.22 b	5.57 a	9.50 b	103.94 c	64.73 b	247.59 b	8.50 b	4.46 a	11.08 a
SOF_3	163.16 b	71.42 a	241.31 a	12.18 a	5.72 a	9.93 a	147.96 b	65.26 a	253.14 a	9.90 a	4.52 a	9.60 b
SOF_4	178.16 a	53.01 c	228.22 c	5.13 d	3.84 b	7.51 d	154.58 a	41.27 c	240.77 c	4.73 d	3.21 c	8.74 c
SSF_0	42.18 g	27.29 g	108.46 g	3.75 ef	2.60 e	5.74 f	35.96 g	21.15 h	109.80 g	3.51 f	2.27 e	6.05 f
SSF_1	73.94 e	39.44 e	175.34 e	9.04 b	4.06 b	8.05 c	65.71 e	34.47 e	178.06 e	8.38 b	3.50 b	7.87 d
CV (%)	24.33	19.20	29.18	14.06	13.62	14.38	25.32	26.84	24.62	23.24	17.44	26.58
LSD (0.05)	0.36	0.37	0.65	0.34	0.31	0.19	0.19	0.17	0.47	0.22	0.18	0.24

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

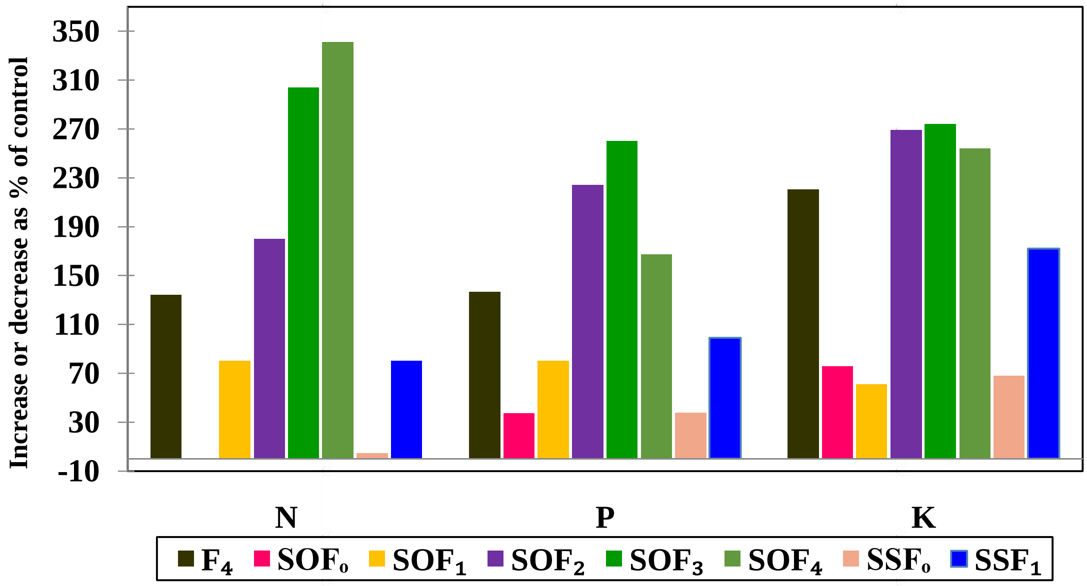

Fig. 4.4a. NPK uptake by shoot of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer at flowering stage during 2016-2017 season.

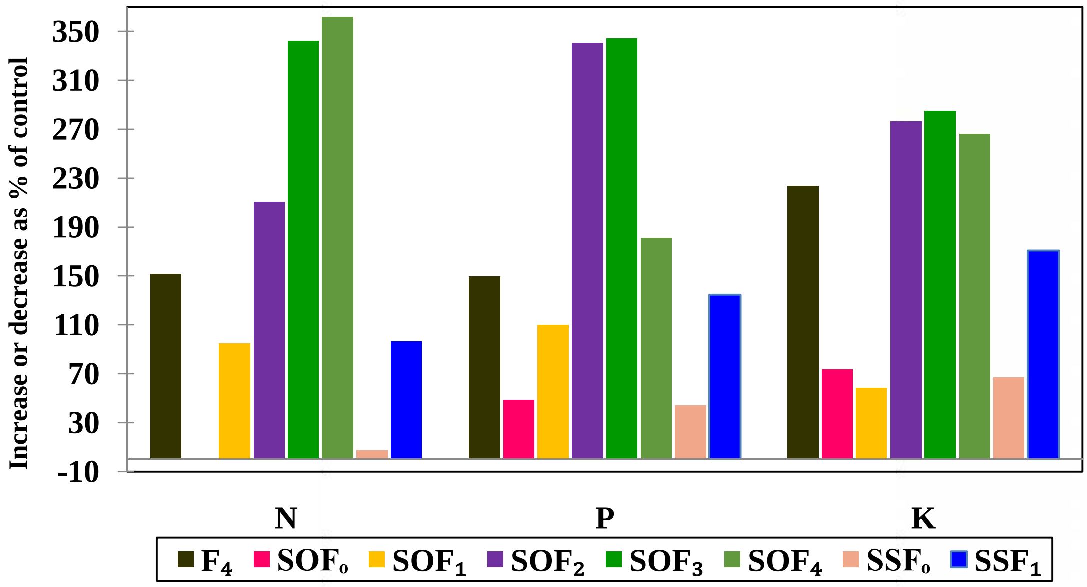

Fig. 4.4b. NPK uptake by shoot of late sown BARI Gom-25 as influenced by NAA and N-fertilizer at flowering stage during 2016-2017 season.

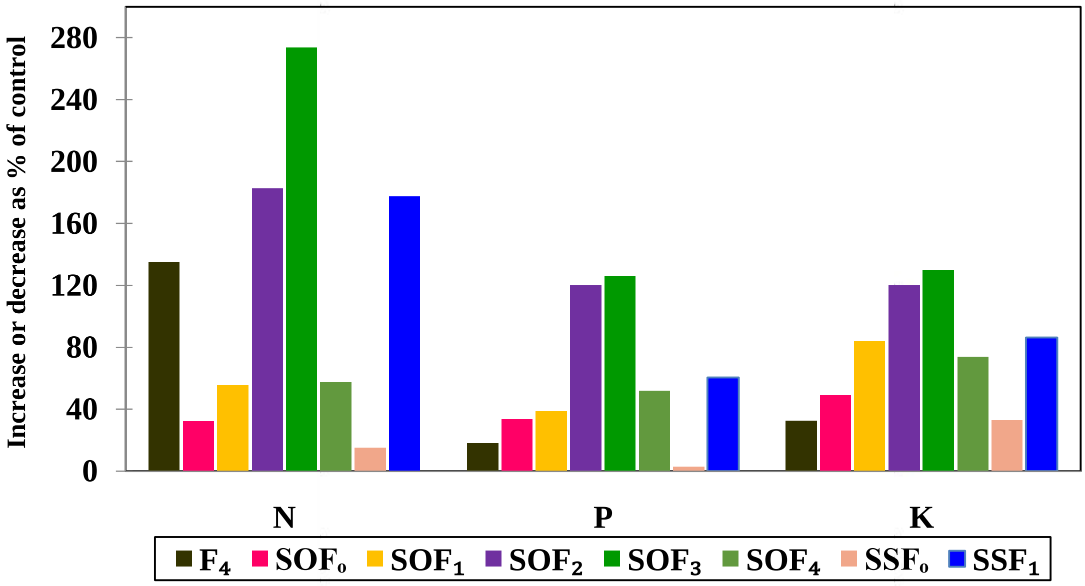

Fig. 4.5a. NPK uptake by root of timely sown BARI Gom-25 as influenced by NAA in combination with N-fertilizer at flowering stage during 2016-2017 season.

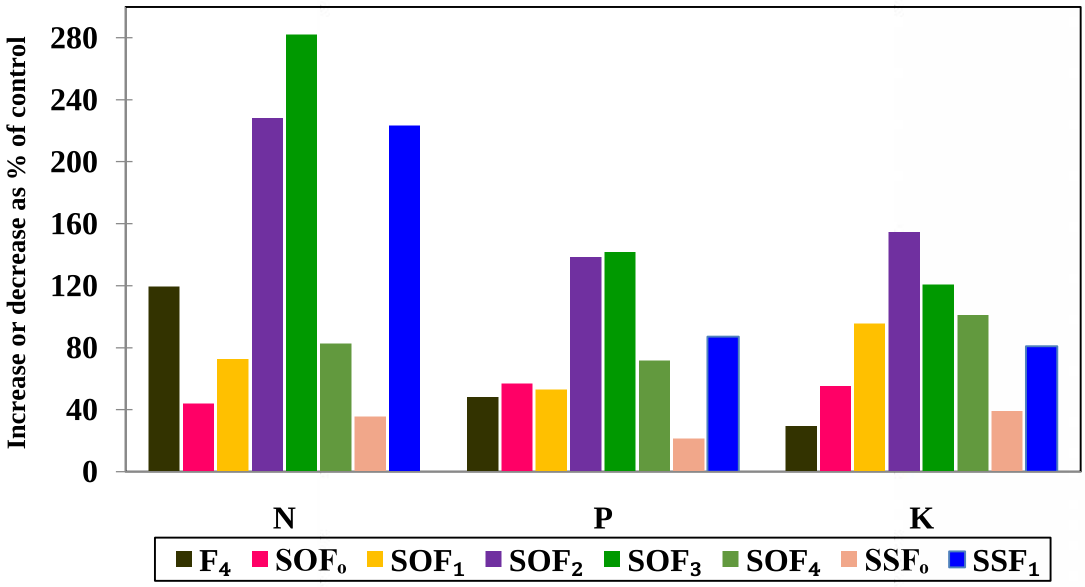

Fig. 4.5b. NPK uptake by root of late sown BARI Gom-25 as influenced by NAA in combination with N-fertilizer at flowering stage during 2016-2017 season.

majority of cases. Results also revealed that NPK uptake by root due to SSF_1 treatment was significantly higher than F_4 treatment.

Late sown

Application of NAA at various N-levels had beneficial effects on NPK uptake by shoot and root (Table XXVa). Significantly maximum N-uptake (154.58 mg/g) by shoot was recorded from SOF_4 followed by SOF_3 treatment (147.96 mg/g). The P and K uptake by shoot due to different treatments varied from 14.69-65.26 and 65.79-253.14 mg/g respectively where, the significantly higher uptake was also found from SOF_3 treatment. The N-uptake by root increased by 35.52-282.24% over the control where, SOF_3 treatment had significantly maximum uptake value. Increases in P-uptake by root due to SOF_3 was 141.71% higher over the control followed by SOF_2 (138.50%) and SSF_1 (87.17%) respectively. In case of K-uptake by root, significantly maximum value (11.08 mg/g) was noted from SOF_2 treatment but followed by SOF_3 (9.60 mg/g). Results indicated that application of SOF_2, SOF_3 and SOF_4 treatments had significantly higher uptake capacity than F_4 treatment in both sowing condition except N uptake by root due to SOF_4 treatment. .

At grain filling stage

Timely sown

Application of NAA at varying N-levels had remarkable effects on NPK uptake by shoot and root where treatment means varied significantly in majority of cases (Table XXVb). The maximum N (169.43 mg/g), P (51.01 mg/g), K (229.25 mg/g) uptake by shoot was observed from SOF_4 treatment followed by SOF_3 except K uptake. Positive influences in NPK uptake by root was also noticed from all treatments. The minimum increase in N-uptake by root due to SOF_1 and maximum due to SOF_4 treatment was 1.48 and 72.41% over the control respectively. The maximum P-uptake by root was obtained from SOF_2 (2.45%) although statistically similar to SOF_1, SOF_4 and SSF_1 but significantly higher than rest of the treatments. The K-uptake by root increased by 15.48-68.39% where the minimum and maximum was found from SOF_3 and SSF_1 treatments respectively.

Table 4.XXVb. Effects of NAA and N-fertilizer on NPK uptake (mg/g) by shoot and root of timely and late sown BARI Gom-25 at grain filling stage during 2016-2017 season.

	Timely sown						Late sown					
	Shoot			Root			Shoot			Root		
Treatments	N	P	K	N	P	K (mg/g)	N	P	K	N	P	K
Control	33.02 i	20.63 g	86.95 i	2.03 f	1.62 d	3.10 f	26.33 i	15.89 g	87.60 h	1.71 g	1.32 f	3.30 h
F_4	49.62 g	42.36 d	172.45 e	2.92 b	1.76 cd	3.71 de	44.13 g	35.20 c	171.36 d	2.51 c	1.43 f	3.59 g
SOF_0	49.04 h	28.93 f	124.55 g	2.28 d	1.89 c	3.88 d	43.73 h	23.89 f	123.45 f	1.89 f	1.69 e	4.03 f
SOF_1	103.49 d	29.06 f	146.67 f	2.06 ef	2.31 a	4.37 c	93.69 d	25.31 e	150.93 e	1.74 g	2.14 bc	4.62 d
SOF_2	79.38 e	37.27 e	213.47 b	2.39 d	2.45 a	4.45 bc	71.73 e	31.78 d	205.99 c	2.00 ef	2.25 b	4.49 d
SOF_3	120.37 b	45.93 b	204.14 d	2.23 de	1.78 cd	3.58 e	116.16 b	40.52 b	206.09 c	2.94 b	2.49 a	5.46 a
SOF_4	169.43 a	51.01 a	229.25 a	3.50 a	2.33 a	4.46 bc	155.34 a	41.57 a	240.42 a	3.20 a	2.04 cd	4.87 c
SSF_0	68.79 f	20.74 g	98.13 h	2.61 c	2.10 b	4.62 b	64.10 f	17.19 g	96.33 g	2.01 e	1.73 e	4.28 e
SSF_1	112.78 c	42.70 c	205.86 c	2.93 b	2.43 a	5.22 a	106.92 c	36.00 c	207.27 b	2.39 d	1.92 d	5.20 b
CV (%)	17.20	9.74	13.56	19.02	16.06	15.35	29.17	13.72	23.23	22.65	19.84	15.45
LSD (0.05)	0.36	0.29	0.64	0.18	0.17	0.23	0.24	0.26	0.17	0.11	0.13	0.13

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

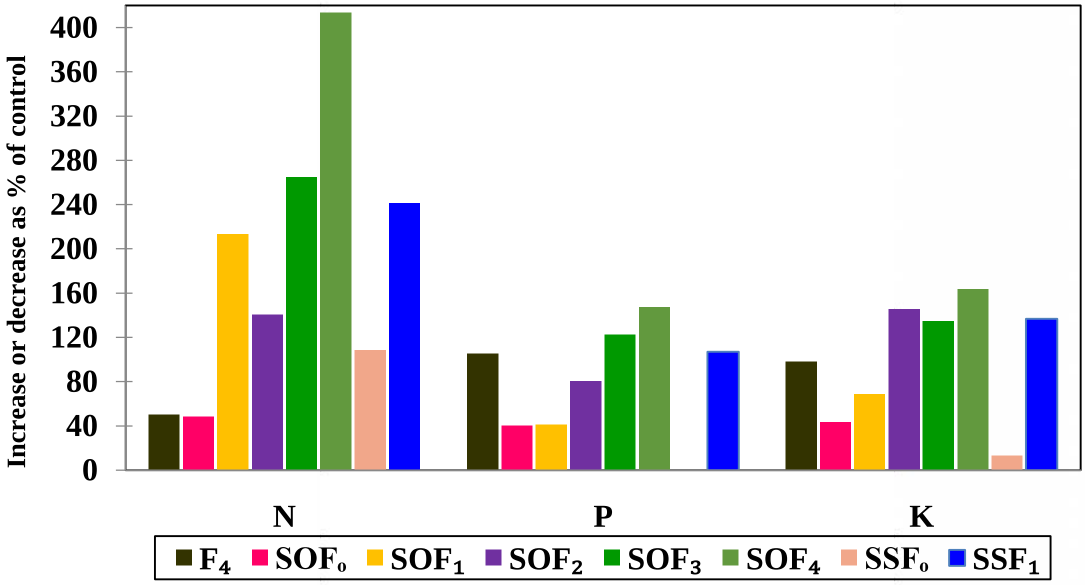

Fig. 4.6a. NPK uptake by shoot of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer at grain filling stage during 2016-2017 season.

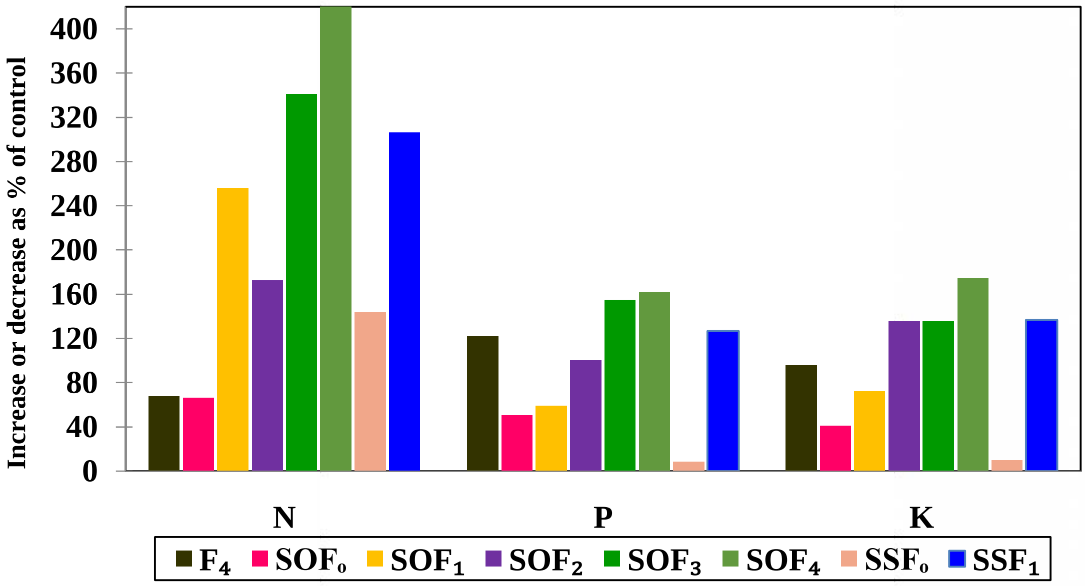

Fig. 4.6b. NPK uptake by shoot of late sown BARI Gom-25 as influenced by NAA and N-fertilizer at grain filling stage during 2016-2017 season.

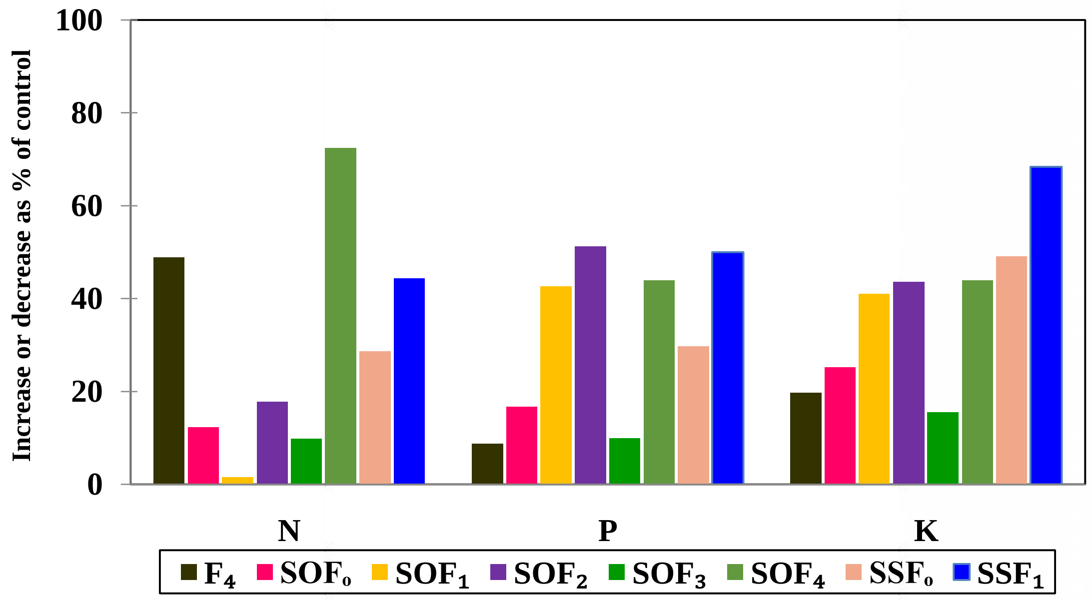

Fig. 4.7a. **NPK uptake by root of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer at grain filling stage during 2016-2017 season.**

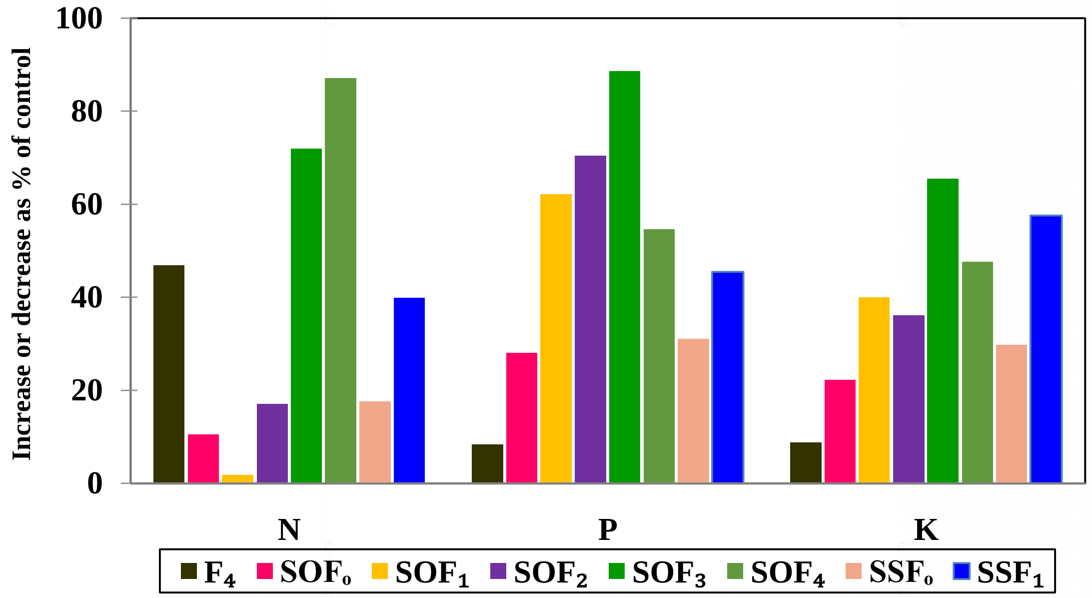

Fig. 4.7b. **NPK uptake by root of late sown BARI Gom-25 as influenced by NAA and N-fertilizer at grain filling stage during 2016-2017 season.**

Late sown

The NPK uptake by shoot and root was optimistically improved by different treatments where, significantly highest uptake was noted from SOF_4 treatment except P and K uptake by root (Table XXVb). Application of SOF_3 and SOF_4 treatments also resulted significantly higher NPK uptake than F_4 treatment in all cases.

At harvest

Timely sown

Both increase and decrease in NPK uptake by shoot, root and grain were observed following different treatments where, the maximum was noted mostly from SOF_3 treatment (Table XXVc). The N uptake by shoot increased up to 13.81-160.27% over control however, the only decrease was recorded from SSF_0 treatment. Most of the treatments had positive response on P uptake by shoot where, SOF_3 treatment (34.67 mg/g) produced significantly higher value than other treatments although SOF_0 and SSF_0 treatment reduced P uptake significantly. Increase in K uptake due to F_4, SOF_2, SOF_3, SOF_4 and SSF_1 treatments ranged from 14.76-91.26% over control whereas rest of the treatments reduced uptake capacity significantly. The N, P and K uptake by root was both positively and negatively influenced by different treatments and varied from 3.05-5.07, 1.21-2.20 and 2.35-3.60 mg/g respectively. Significantly maximum NPK uptake by grain was obtained from SOF_3 followed by SOF_4 and SOF_2 treatments. However, NPK uptake by grain due to SOF_0 and SSF_0 treatments were lower than the control.

Late sown

Results presented in Table XXVc showed that N-uptake by shoot decreased following both SOF_0 and SSF_0 treatments where, significantly lowest value (11.82 mg/g) was noted from SSF_0 treatment. However, N-uptake by shoot due to other treatments increased by 5.18-139.77% over control. Significantly highest P-uptake by shoot was obtained from SOF_2 treatment which was 65.63% higher over the control whereas, the only decrease due to SSF0 treatment was 8.20% lower than control. The K-uptake by shoot due to SOF_3 (249.00 mg/g) and SOF_4 (240.91 mg/g) treatments were significantly higher than rest of the treatments.

Table 4.XXVc. Effects of NAA and N-fertilizer on NPK uptake (mg/g) by shoot, root and grain of timely and late sown BARI Gom-25 at harvest during 2016-2017 season.

	Timely sown									Late sown								
	Shoot			Root			Grain			Shoot			Root			Grain		
Treatments	N	P	K	N	P	K	N	P	K	N (mg/g)	P	K	N	P	K	N	P	K
Control	37.58 g	14.87 g	157.84 f	3.69 c	1.37 d	3.60 a	74.42 g	10.98 g	7.29 g	19.69 g	7.68 f	212.67 c	2.71 d	0.20 g	4.99 d	80.97 i	12.25 g	9.18 i
F_4	72.48 c	28.01 c	216.23 d	4.32 b	1.21 e	2.98 cd	172.64 d	24.22 d	22.42 d	33.72 d	12.46 b	146.32 e	4.39 a	1.16 a	5.25 c	171.09 c	24.15 c	23.08 d
SOF_0	42.77 f	12.44 i	146.02 h	3.05 e	1.37 d	3.06 a	65.69 i	9.84 h	8.55 f	16.51 h	9.51 e	115.82g	2.14 e	0.75 e	4.89 d	89.09 h	13.82 f	12.52 g
SOF_1	47.74 f	19.29 d	151.07 g	3.62 cd	1.41 cd	3.22 b	121.72 f	17.97 f	17.77 e	24.25 e	9.39 e	123.50f	3.26 c	0.87 d	4.40 e	133.71 f	19.54 e	19.49 e
SOF_2	60.33 d	16.48 f	181.13 e	5.07 a	1.50 bc	2.36 e	173.51 c	24.80 c	24.80 c	47.21 a	10.60 d	197.94d	3.91 b	0.98 c	3.99 f	166.56 d	23.88 c	24.13 c
SOF_3	97.81 a	34.67 a	301.88 a	4.85 a	2.20 a	2.84 d	220.88 a	29.45 a	28.75 a	39.86 c	12.72 a	249.00a	4.34 a	0.36 f	3.73 g	213.08 a	28.58 a	28.20 a
SOF_4	88.19 b	31.48 b	296.47 b	4.05 b	1.58 b	2.07 f	202.37 b	27.90 b	26.78 b	43.11 b	9.48 e	240.91b	4.40 a	1.06 b	2.73 h	190.04 b	26.57 b	26.08 b
SSF_0	27.59 h	13.00 h	120.80 i	3.31 de	2.17 a	2.85 d	68.22 h	9.93 h	6.80 g	11.82 i	7.05 g	75.14h	2.09 f	1.04 bc	8.92 a	91.88 g	13.91 f	10.13 h
SSF_1	50.82 e	17.97 e	218.43 c	3.65 c	1.57 b	2.35 e	150.14 e	21.46 e	17.19 e	20.71 f	11.20 c	72.32i	4.49 a	1.05 b	8.52 b	149.90 e	20.92 d	18.01 f
CV (%)	18.49	17.94	13.25	17.48	21.91	16.93	40.64	37.80	25.95	22.55	18.64	14.72	17.14	18.92	18.04	31.61	27.91	25.39
LSD (0.05)	0.47	0.49	0.49	0.33	0.12	0.16	0.86	0.39	0.58	0.13	0.15	0.34	0.15	0.06	0.11	0.68	0.57	0.48

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

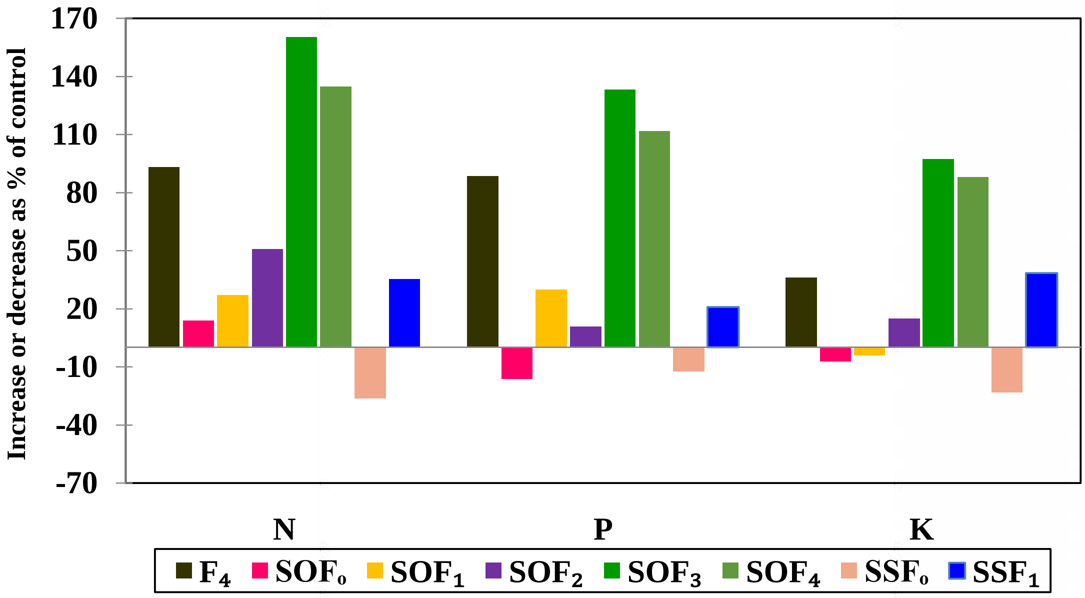

Fig. 4.8a. NPK uptake by shoot of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer at harvest during 2016-2017 season.

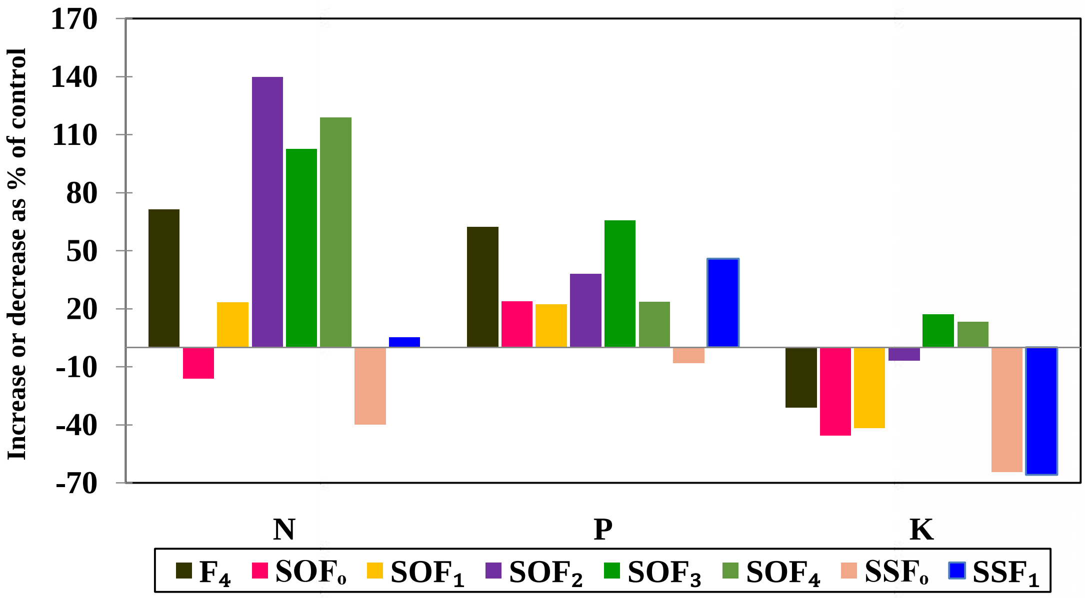

Fig. 4.8b. NPK uptake by shoot of late sown BARI Gom-25 as influenced by NAA and N-fertilizer at harvest during 2016-2017 season.

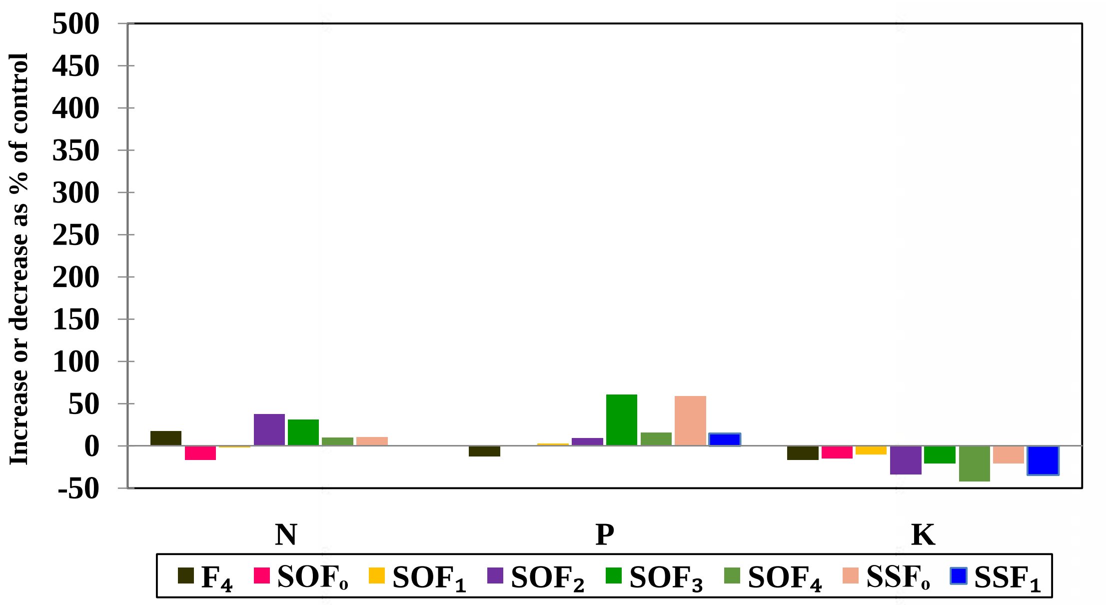

Fig. 4.9a. NPK uptake by root of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer at harvest during 2016-2017 season.

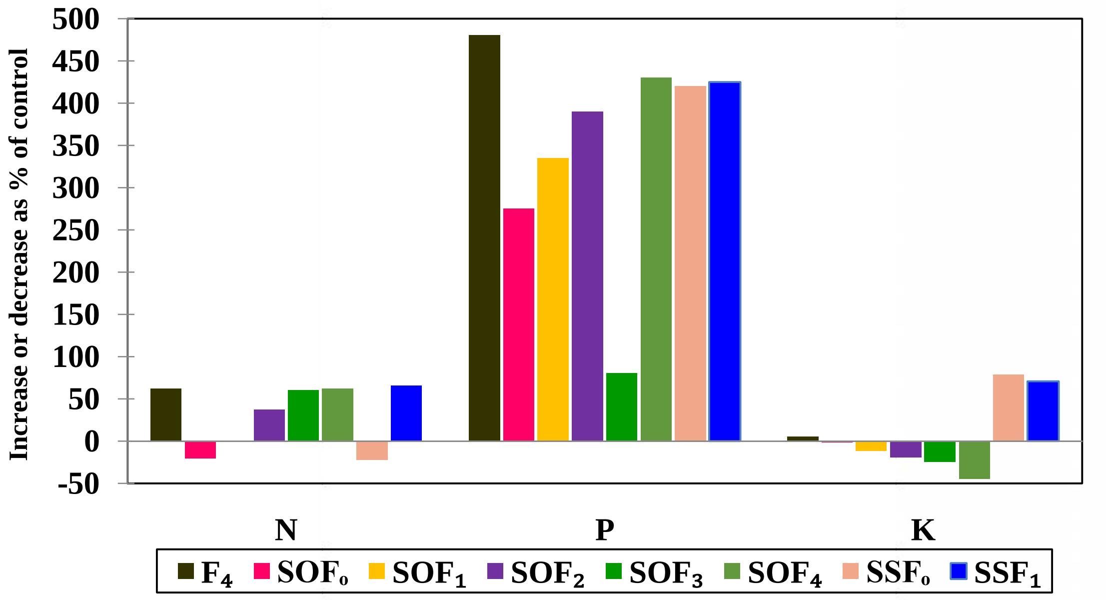

Fig. 4.9b. NPK uptake by root of late sown BARI Gom-25 as influenced by NAA and N-fertilizer at harvest during 2016-2017 season.

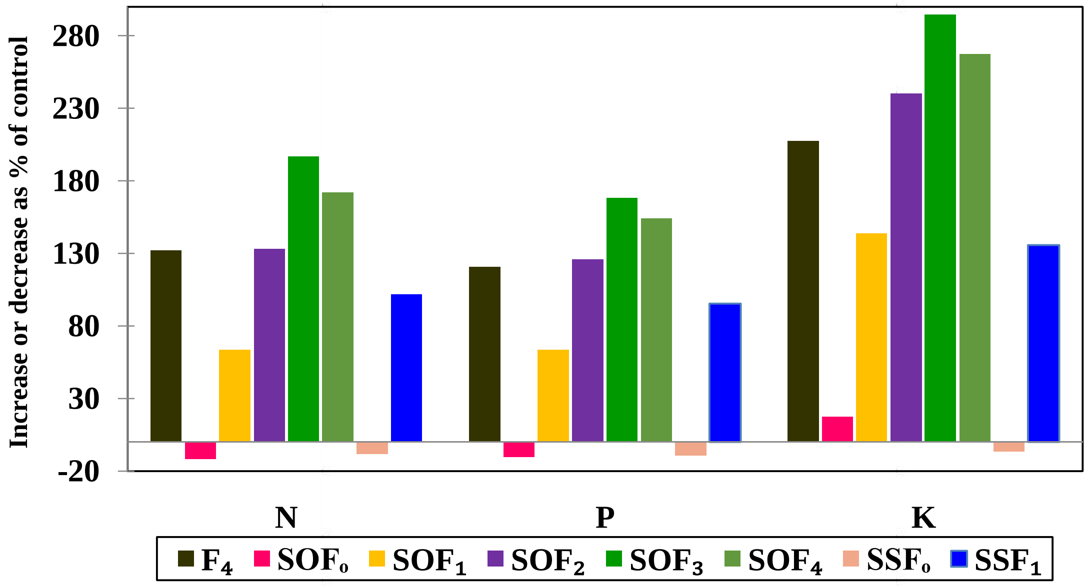

Fig. 4.10a. NPK uptake by grain of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer at harvest during 2016-2017 season.

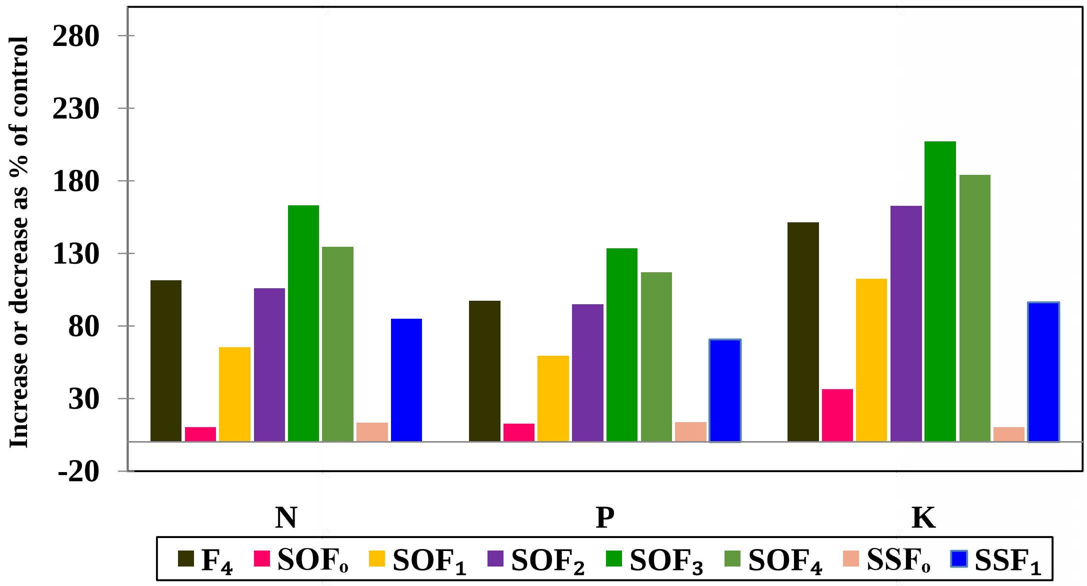

Fig. 4.10b. NPK uptake by grain of late sown BARI Gom-25 as influenced by NAA and N-fertilizer at harvest during 2016-2017 season.

The maximum N-uptake by root (4.49 mg/g) due to SSF_0 treatment although statistically identical to F_4 (4.39 mg/g), SOF_3 (4.34 mg/g) and SOF_4 (4.40 mg/g) treatments but significantly higher than rest of the treatments. Higher amount of P-uptake was obtained from different NAA treatments at varying N-levels where, the maximum (1.16 mg/g) was found from F_4 treatment. In case of K-uptake by root, F_4, SSF_0 and SSF_1 treatments had resulted significantly higher value than control however decreased following rest of the treatments. Application of all treatments had stimulatory effects on NPK uptake by grain where the maximum increase was noted from SOF_3 followed by SOF_4 treatment.

4.4.3.3 NUE of shoot, root and grain

Timely sown

Nitrogen use efficiency (NUE) of wheat was significantly influenced by NAA treatments in combination with different doses of N-fertilizer (Table XXVI). At flowering stage, different treatments produced significantly higher NUE of shoot and total plant than control where, the maximum value was noted from SOF_3 treatment. Similar results of increases in NUE of shoot and total plant were also obtained at grain filling stage but significantly maximum was found from SOF_1 treatment followed by SSF_1. At both flowering and grain filling stages, NUE of root varied from 0.003-0.081 and -0.003-0.005 KgN/KgN respectively but with both positive and negative responses. At harvest, application of NAA at varying N-levels had beneficial effect on NUE of root, grain and total plant with significant variations. However, NUE of shoot due to SOF_3, SOF_4 and SSF_1 treatments were significantly higher than F_4. The total NUE at harvest (1.622 KgN/KgN) was recorded highest from SSF_1 treatment.

Late sown

At flowering stage, NUE of shoot and total plant following various treatments were significantly higher than F_4 treatment (Table XXVI). The NUE of shoot and total plant were positively influenced due to application of all treatments but significantly highest value was obtained from SOF_1 treatments. At both flowering and grain filling stage, NUE of root responded with positive and negative influences. NAA in combination with N-levels had resulted significantly higher NUE than F_4 except NUE of root due to SOF_4 treatment.

Table 4.XXVI. Effects of NAA and N-fertilizer on NUE (Kg N/Kg N) of timely and late sown BARI Gom-25 at three different stages.

	Timely sown										Late sown									
	Flowering			Grain filling			Harvest				Flowering			Grain filling			Harvest			
Treatments	Shoot	Root	Total	Shoot	Root	Total	Shoot	Root	Grain (Kg N/Kg N)	Total	Shoot	Root	Total	Shoot	Root	Total	Shoot	Root	Grain	Total
Control	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F_4	0.217 f	0.018 c	0.235 f	0.066 f	0.004 a	0.070 f	0.140 d	0.003 c	0.393 e	0.536 f	0.203 e	0.012 d	0.215 f	0.071 f	0.003 bc	0.074 f	0.056 f	0.007 d	0.360 f	0.423 f
SOF_0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SOF_1	0.504 d	0.012 d	0.516 e	0.838 a	-0.003 c	0.835 a	0.076 e	0.009 b	0.862 b	0.947 d	0.486 c	0.012 d	0.498 d	0.769 a	-0.002d	0.767 a	0.119 d	0.017 b	0.686 b	0.822 c
SOF_2	0.585 b	0.039 b	0.624 b	0.243 e	0.001 b	0.244 e	0.141 d	0.016 a	0.863 b	1.020 c	0.563 b	0.038 b	0.601 b	0.224 e	0.001 c	0.225 e	0.246 a	0.014 c	0.620 d	0.880 b
SOF_3	0.648 a	0.041b	0.689 a	0.375 d	0.000 b	0.375 d	0.290 b	0.009 b	0.817 c	1.116 b	0.602 a	0.032 c	0.634 a	0.381 d	0.006 a	0.387 d	0.123 c	0.012 c	0.653 c	0.788 d
SOF_4	0.553 c	0.003 e	0.556d	0.480 c	0.005 a	0.485 c	0.182 c	0.004 c	0.547 d	0.733 e	0.484 c	0.004 e	0.488 e	0.446 c	0.005 ab	0.451 c	0.106 e	0.009 d	0.404 e	0.519 e
SSF_0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SSF_1	0.489 e	0.081 a	0.570 c	0.677 b	0.005 a	0.682 b	0.357 a	0.005 bc	1.260 a	1.622 a	0.459 d	0.075 a	0.534 c	0.659 b	0.006 a	0.665 b	0.137 b	0.037 a	0.893 a	1.067 a
CV (%)	27.89	38.72	27.54	28.69	18.93	51.97	29.58	28.07	35.23	34.72	27.88	38.93	27.89	27.02	10.99	26.47	34.31	36.81	30.21	29.49
LSD (0.05)	0.002	0.004	0.004	0.005	0.002	0.004	0.005	0.004	0.011	0.014	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.007	0.006

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Significantly maximum NUE of total plant at flowering, grain filling and at harvest were obtained from SOF_3 (0.634 KgN/KgN), SOF_1 (0.767 KgN/KgN) and SSF_1 (1.067 KgN/KgN) treatments respectively.

4.4.3.4 Comparative analysis among selected treatments on some biochemical parameters of timely sown wheat

Three treatments *viz.* control, F_4 (100% of recommended dose N-fertilizer) and SOF_3 (Best performed treatment) were selected for comparative analysis on some biochemical parameters of timely sown wheat grain.

4.4.3.4.1 Nutritional parameters of grain

Results presented in Table XXVII indicated that carbohydrate content significantly decreased following F_4 and SOF_3 treatments where, the maximum decrease due to SOF_3 was 3.72% than control. Protein content of grain significantly increased following F_4 and SOF_3 treatments where it was increased by 13.92 and 16.94% over control, respectively. The maximum fat content (1.69 %) was obtained from F_4 treatment although statistically at par to SOF_3 (1.66%) but significantly higher than control. Starch content of grains increased significantly following both F_4 and SOF_3 treatments. Starch content due to SOF_3 increased by 3.91 and 1.64% over control and F_4 treatments respectively. Moisture content of grains due to F_4 and SOF_3 treatments reduced by 3.15 and 9.26% than control but with significant variations. Crude fibre content of grains was significantly influenced by different treatments where, the minimum (1.65%) and maximum (1.94%) and value was noted from control and F_4 treatments respectively. Ash content of grains were recorded significantly higher from F_4 and SOF_3 treatments where the increase was 8.98 and 17.37% over the control respectively. Total sugar content of grain was significantly responded by both F_4 and SOF_3 treatments where the maximum (5.65%) was noted from SOF_3. Reducing sugar content due to F_4 and SOF_3 treatments increased by 18.57 and 31.43% over the control with significant differences.

4.4.3.4.2 Amino acid contents of grain

Amino acid contents of grains were both significantly and non-significantly influenced by different treatments (Table XXVIII). All the amino acids *viz.* aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, methionine, isoleucine,

Table 4.XXVII. Effects of NAA and N-fertilizer on nutritional parameters of grain of timely sown BARI Gom-25.

Treatments	Carbohydrate	Protein	Fat	Starch	Moisture	Crude fibre	Total Ash	Total sugar	Reducing sugar
					(%)				
Control	69.30 a	15.23 c	1.35 b	49.89 c	10.80 a	1.65 c	1.67 c	5.47 c	0.70 c
F_4	66.72 c	17.35 b	1.69 a	51.84 b	10.46 b	1.96 a	1.82 b	5.58 b	0.83 b
SOF_3	66.93 b	17.81 a	1.66 a	52.69 a	9.80 c	1.84 b	1.96 a	5.65 a	0.92 a
CV (%)	1.73	6.93	10.35	2.36	4.12	7.36	6.86	1.46	11.91
LSD(0.05)	0.05	0.04	0.03	0.06	0.03	0.05	0.03	0.06	0.04

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XXVIII. Effects of NAA and N-fertilizer on amino acid contents of grain of timely sown BARI Gom-25.

Treatments	Aspartic acid	Threonine	Serine	Glutamic acid	Glycine	Alanine	Valine	Methionine	Isoleucine	Leucine	Tyrosine	Histidine	Lysine	Arginine
							(%)							
Control	0.63 c	0.31	0.48 b	3.17 c	0.45 b	0.42 a	0.47 b	0.23 a	0.38 b	0.75 c	0.26 b	0.30 b	0.86 c	1.62 c
F_4	0.72 b	0.35	0.55 a	3.61 b	0.51 a	0.48 a	0.54 a	0.26 a	0.43 a	0.85 b	0.29 a	0.34 a	0.98 b	1.85 b
SOF_3	0.74 a	0.35	0.56 a	3.71 a	0.53 a	0.49 a	0.56 a	0.26 a	0.44 a	0.88 a	0.30 a	0.35 a	1.01 a	1.89 a
CV (%)	7.51	8.81	8.26	6.95	7.78	7.18	8.09	8.85	7.57	7.16	9.21	8.07	7.23	6.97
LSD(0.05)	0.03	NS	0.04	0.03	0.03	0.18	0.03	0.04	0.03	0.02	0.03	0.02	0.02	0.02

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

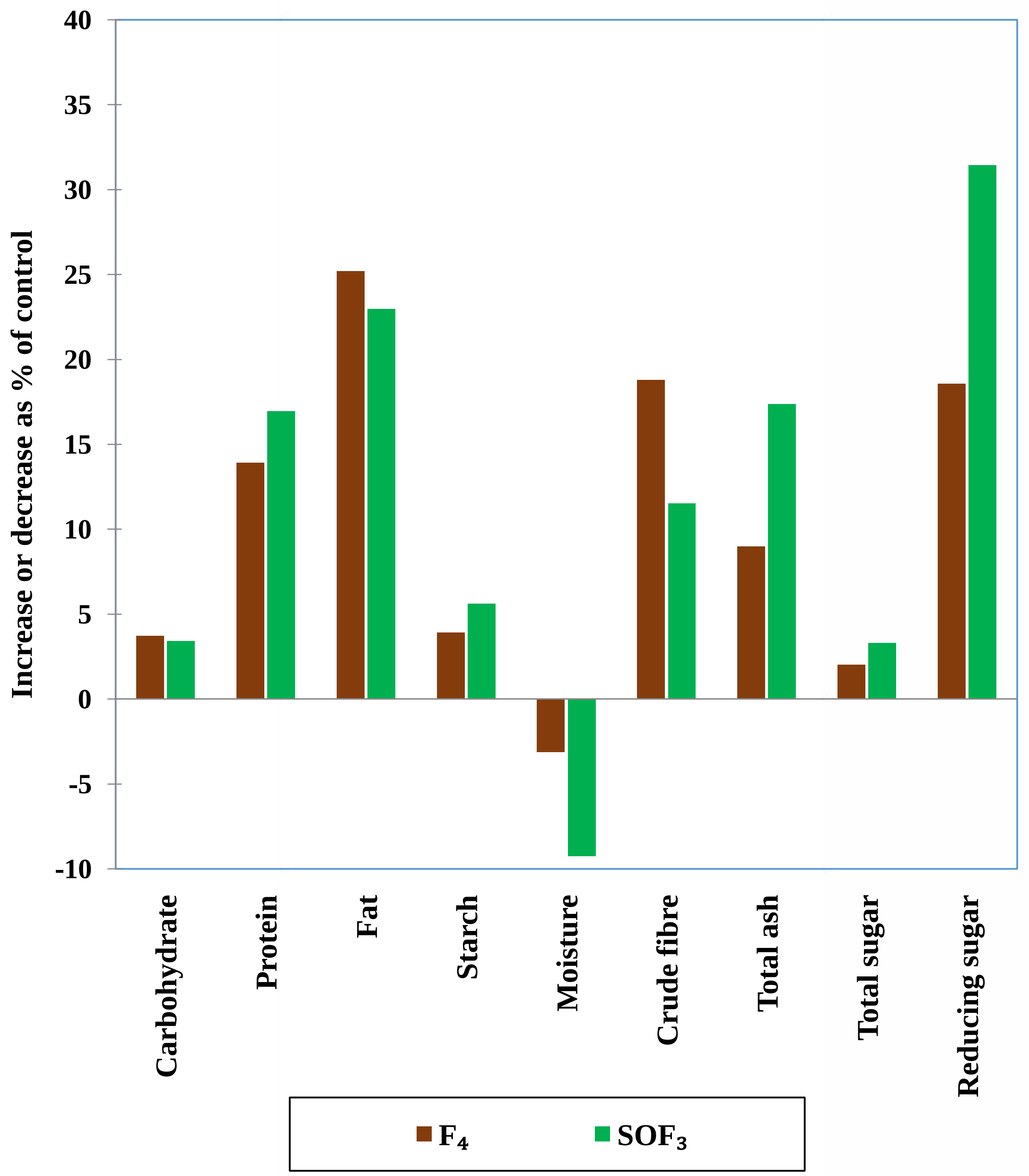

Fig. 4.11. Nutritional parameters of grain of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer during 2016-2017 season.

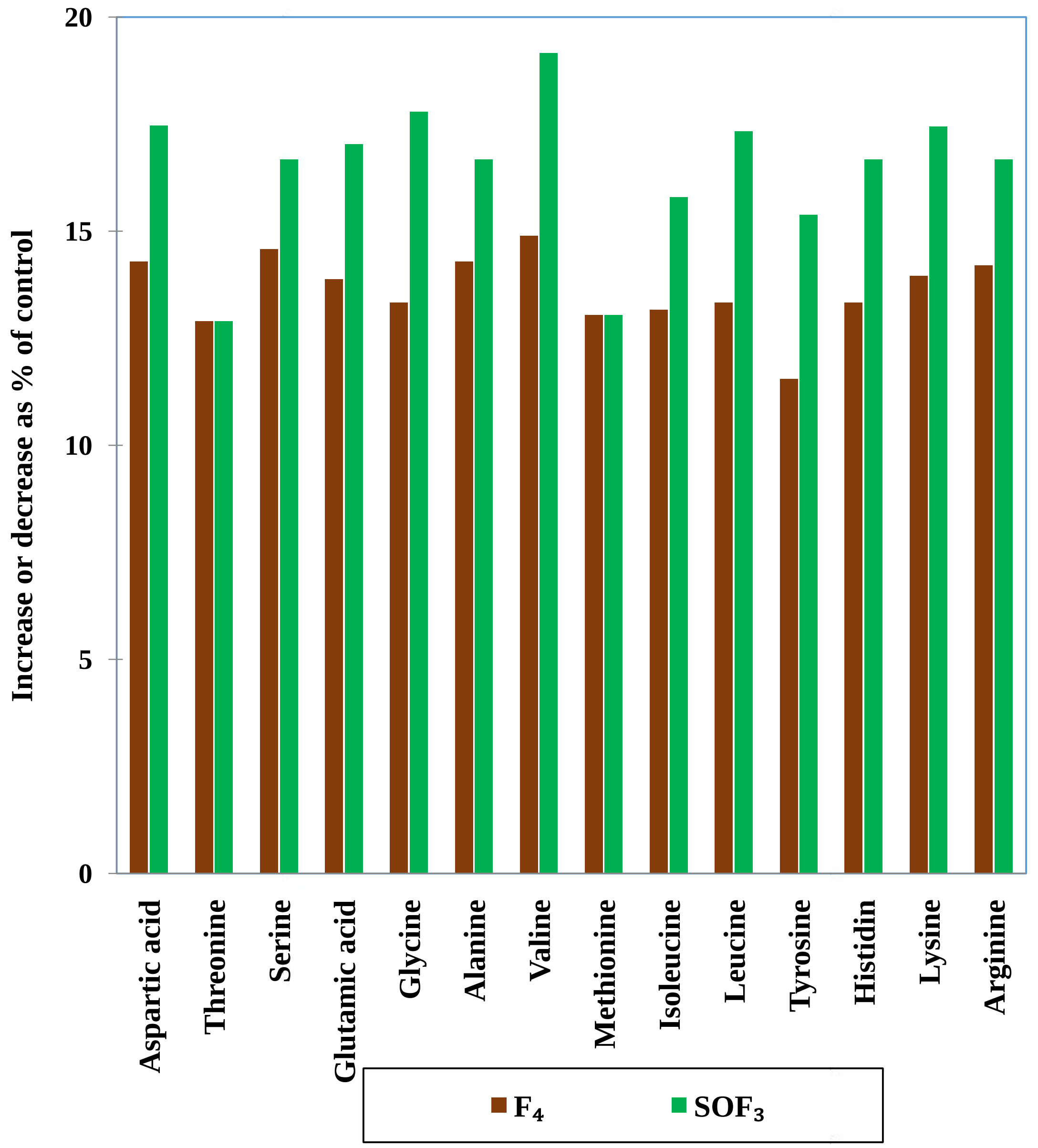

Fig. 4.12. Amino acid contents of grain of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer during 2016-2017 season.

leucine, tyrosine, histidine, lysine and arginine were increased following different treatments. The maximum amino acid contents were recorded due to SOF_3 treatment and in case of threonine and methionine in addition to SOF_3 treatment the maximum was recorded from F_4 treatment. The amount of aspartic acid, glutamic acid, leucine, lysine and arginine recorded were significantly higher than both control and F_4 treatments, whereas, those of serine, glycine, valine, isoleucine, tyrosine and histidine are statistically not different from F_4 treatment. Increases in aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, histidine, lysine and arginine content due to SOF_3 were 17.46, 12.90, 16.67, 17.03, 17.78, 16.67, 19.15, 13.04, 15.79, 17.33, 15.38, 16.67, 17.44 and 16.67% over the control respectively. Except threonine and methionine which were recorded same as that of F_4 treatment aspartic acid, serine, glutamic acid, glycine, alanine, valine, isoleucine, leucine, tyrosine, histidine, lysine and arginine increased by 2.78, 1.82, 2.77, 3.92, 2.08, 3.70, 2.33, 3.53, 3.45, 2.94, 3.06 and 2.16% over F_4 treatment respectively. However the increase of aspartic acid, serine, glutamic acid, glycine, alanine, valine, isoleucine, leucine, tyrosine, histidine, lysine and arginine due to F_4 treatment were 14.29, 14.58, 13.88, 13.33, 14.29, 14.89, 13.33, 11.54, 13.33, 13.95 and 14.20% over control respectively.

4.4.3.4.3 Enzyme activities of grain

Enzyme activities of grain were positively influenced by different treatments but with both significant and non-significant responses (Table XXIX). Significantly higher α-amylase content was recorded from SOF_3 treatment followed by F_4 where, the maximum increase due to SOF_3 treatment was 15.39% over the control. Application of SOF_3 treatment also resulted significantly higher protease activity (0.56 unit/g) than control (0.44 unit/g) but statistically at par to F_4 treatment (0.51 unit/g).

4.4.3.4.4 Mineral contents of grain

Mineral contents of grain were responded positively but with both significant and non-significant variations (Table XXX). Significantly higher N content was recorded from both F_4 and SOF_3 treatments where, the maximum amount (2.850%) was found from SOF_3 but statistically not different from F_4 (2.780%).

Table 4.XXIX. Effects of NAA and N-fertilizer on enzyme activities of grain of timely sown BARI Gom-25.

Treatments	α- amylase (unit/g)	Protease (unit/g)
Control	0.52 c	0.44 b
F_4	0.60 b	0.51 ab
SOF_3	0.64 a	0.56 a
CV (%)	9.48	11.23
LSD (0.05)	0.03	0.13

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

Table 4.XXX. Effects of NAA and N-fertilizer on some mineral contents of grain of timely sown BARI Gom-25.

Treatments	Mineral (%)					
	N	P	K	Fe	Ca	Zn
Control	2.440 b	0.364 b	0.299 a	0.006 a	0.049 b	23.050 b
F_4	2.780 a	0.392 a	0.361 a	0.007 a	0.054 b	24.371 a
SOF_3	2.850 a	0.375 ab	0.371 a	0.008 a	0.067 a	22.761 c
CV (%)	6.94	4.48	9.62	15.27	17.81	3.10
LSD (0.05)	0.122	0.021	0.228	0.002	0.009	0.028

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5 % level.

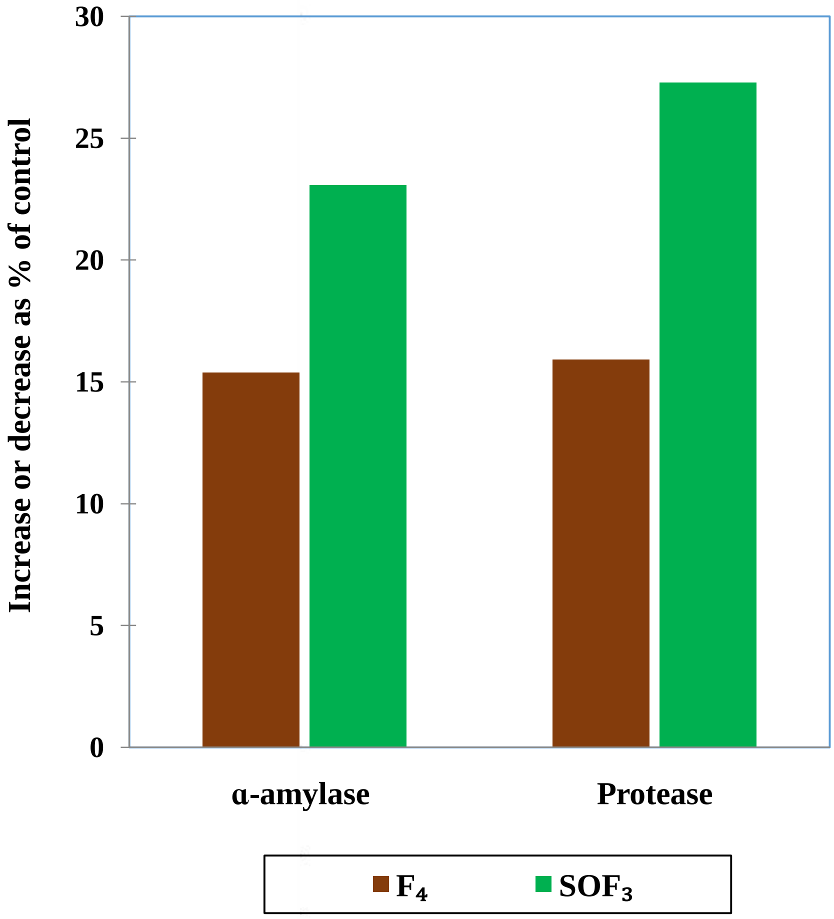

Fig. 4.13. Enzyme activities of grain of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer during 2016-2017 season.

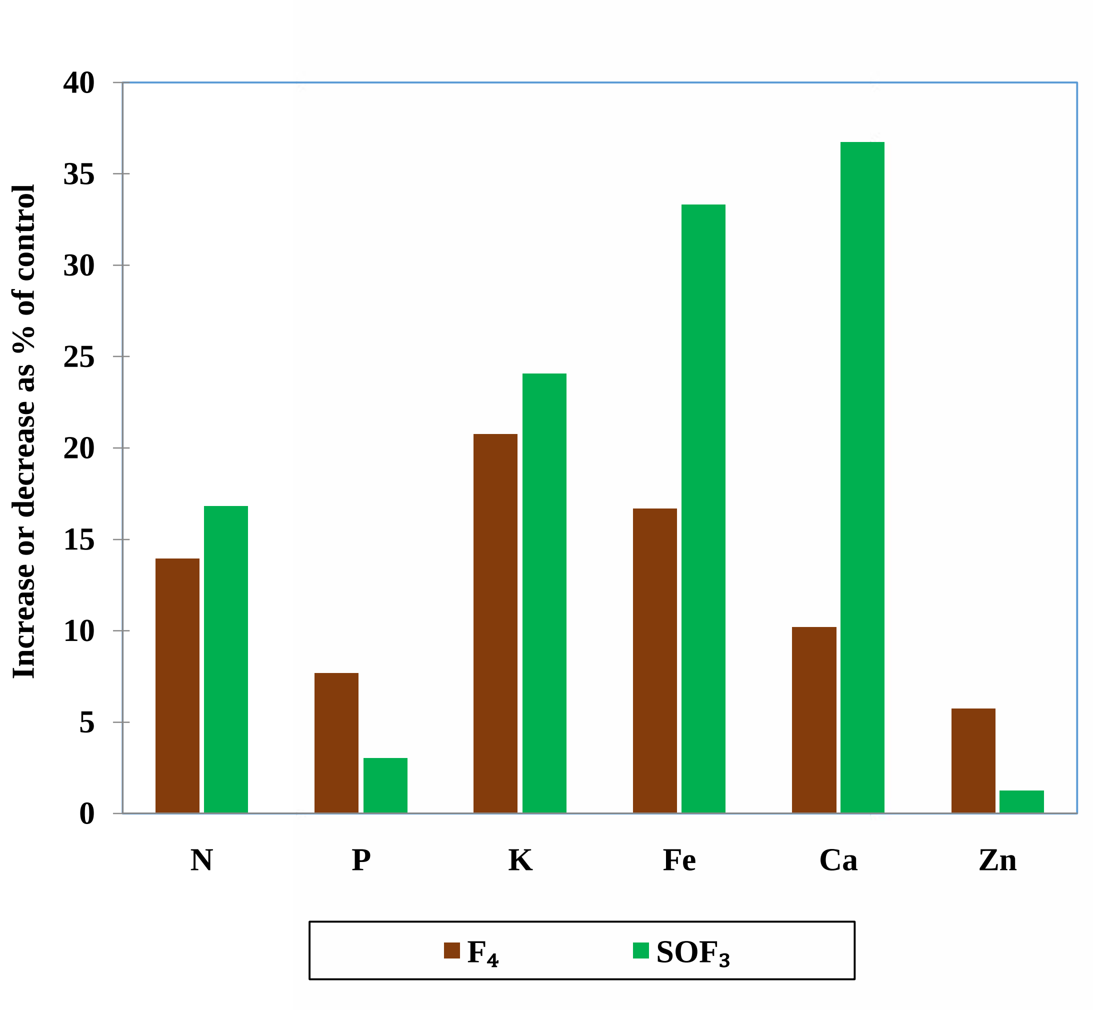

Fig. 4.14. Mineral contents of grain of timely sown BARI Gom-25 as influenced by NAA and N-fertilizer during 2016-2017 season.

The P content of grain was obtained maximum from F_4 treatment but statistically similar to SOF_3 treatments. Increases in P content due to F_4 and SOF_3 treatments were 7.69 and 3.02% higher over the control. The maximum K (0.371%) and Fe (0.008%) content was found from SOF_3 treatment but statistically similar to rest of the treatments. Application of SOF_3 treatment also produced significantly highest Ca content where, it was increased by 36.73 and 24.07% over the control and F_4 treatments respectively. The maximum Zn content (24.371%) was obtained from F_4 which was significantly higher than other treatments and in this case the minimum was noted from SOF_3 (22.761%) treatment.

DISCUSSION

Crop production is the result of complex interaction of plant with environment like soil and climate and also on crop management. A proper manipulation of these interacting factors could produce higher yields. Wheat is the most widely cultivated and the most consumed food crop all over the world (Mehraban 2013). The growth and development of wheat is regulated by a number of factors which can be modified by various ways. Sowing time is a vital issue that affects phenophases and grain yield and its components of wheat (Kiss *et al.* 2013). Longer vegetative growth period due to sowing at proper time, resulted in higher radiation use efficiency and better dry matter mobilization and higher values for grain yield and its components (Sun *et al*. 2013, Eslami *et al.* 2014, Anwar *et al*. 2015). Sowing time may also have an impact on quality characters of wheat especially protein content.

Inorganic nitrogen compounds although account for less than 5% of the total nitrogen in soil (Brady and Weil 2008) but are the main form of the element absorbed by most plants. Inorganic and organic fertilizers are applied to maintain the nutritional condition of different cropping systems. Wheat yields especially those of newly developed genotypes are among the most depending nitrogen fertilization plant species (Hirel *et al.* 2001). The use of nitrogen fertilizers increased 100 fold over the last 100 years to improve grain yield and protein content (López-Bellido *et al*. 2008, Giambalvo *et al*. 2010). But application of excess fertilizer is proven to cause a number of environmental and ecological problems. Therefore an agricultural system should include yield and environmental quality during management.

Plant growth regulators (PGRs) are the chemical which enhance the plant growth when applied in very minute quantity. They exert quite different effects in different plants; and sometime the same PGR at identical concentrations can have quite different effects on different organs of the same plant. Moreover, different concentrations of the same chemicals can elicit different responses in the same tissue (Ridge 1991). They can promote, inhibit or otherwise modify physiological processes. Despite the fact that plants are capable of synthesizing phytohormones and absorbing phytohormones generated by soil microorganisms, they may also respond to exogenous application of hormones during certain growth stage and under specific conditions (Frankenberger and Arshed 1995). Plant may not synthesize enough endogenous phytohormones for optimal growth and development under suboptimal climatic and environmental conditions. Proper exogenous application of PGRs may enhance plant growth and tolerance to various stress (Hall *et al.* 1993, Arteca 1996). Recently use of growth stimulating chemicals for increasing production of yield has drawn the attention of plant physiologists all over the world. Auxin and auxin related compounds were some of the first compounds used in agriculture. Metabolism in plants can be altered by the application of growth regulators. These growth stimulating chemicals used in a scientific way are capable of modifying growth and development, increase production of yield and also improve the quality of products. It is increasingly evident that in modern agriculture PGRs have been used in many countries.

Positive influence of Naphthalene acetic acid (NAA) has been reported from different countries of the world to increase growth, development and yield of various economically important crop plants *viz.* rice (Misra and Sahu 1957, Choudhuri *et al.*1980, Sahu and Murty 1981, Grewal and Gill 1986, Naiduv *et al*. 2003, Wang *et al.* 2004), baby corn (Mathukumar *et al.* 2005), barley (Reddy and Rao 1981), wheat (Chen *et al*. 1984), wheat and barley (Orsi and Tallarico 1983, Harsharn and Gill 1985), sorghum (Thakre 1985, Tulsa-Ram *et al*. 1997), pea (Singh *et al*. 1972), sunflower (Vasudevan *et al.* 1967), cowpea (Deshai and Deore 1985, Jain *et al.* 1995), groundnut (Kelaiya *et al.* 1991), lentil (Setia *et al.*1992), turmeric (Rao 1993), fibre hemp (Geel *et al*. 1994), cotton (Patel 1992), tomato (Kar *et al*. 1993), black gram (Lakshmamma and Rao 1996), green gram (Sharma and Sharma 1989), green gram and black gram (Patel and Saxena 1994), french bean (Valio and Schwabe 1978), potato (Puste and Kundo 1995), dolichos bean (Deshai *et al*. 1995), chickpea (Dhingra *et al.* 1995), faba bean (Klasa *et al.* 1996), summer sesame (Tripathy *et al.* 1996) and soybean (Maske *et al.* 1997).

In Bangladesh reports are available relating to the effect of NAA on different crop plants other than cereals (Jahan and Fattah 1991, Jahan *et al.* 1992, Rahman and

Nath 1992, Uddin *et al.* 1994, Karim *et al.* 2006, Karim and Fattah 2007, Ullah *et al.* 2007, Ullah *et al.* 2011, Noor *et al.* 2017). Investigations also revealed that NAA at appropriate concentration had pronounced effect on growth, yield and biochemical components of rice (Adam and Jahan 2011, Adam *et al*. 2012, Jahan and Adam 2014), maize (Akter 2010, Akter 2016) etc. But in case of wheat only a single report relating to the stimulative effect of NAA is available (Jahan and Adam 2013) and reports regarding the effects of NAA in combination with different doses of N fertilizer are also meagre (Islam and Jahan 2016a, Islam and Jahan 2016b). In addition, no report is available on the responses of NAA either as seed soaking or as foliar spray treatments at varying N levels on timely and late sown wheat throughout the world.

In view of the importance of extensive and intensive physiological research needed, the present investigation was undertaken to find out the responses of different physiological, yield and biochemical parameters of wheat to NAA in combination with recommended dose and lower doses of N-fertilizer. The aim was to find out, whether any significant stimulation could be obtained by using lower doses of fertilizers than the recommended one. In all the cases the primary objective was to find out a treatment which will ultimately lead to higher grain yield. During the present study, it was found that following treatments of NAA in combination with different N-fertilizer doses, vegetative and reproductive growth, yield and certain biochemical parameters were affected, but the magnitude of effect depended on the concentrations and nature of NAA treatment, doses of N-fertilizer and also on parameters observed. Different parameters were found to respond differently to NAA treatments depending on fertilizer levels.

Results obtained during 2014-2017 periods on different investigated parameters of wheat plants have been explained, discussed and evaluated in the light of available literature. An attempt has been made to interpret the results obtained and also the prospect of using NAA to improve the productivity of wheat plant as well as quality of grain.

Plant height is a varietal character of any crop plant, but it may be influenced by sowing time, NAA, fertilizer levels, environmental conditions and also by management practices. Results obtained during present investigation indicated that the maximum plant height was recorded from BARI Gom-24 at most of the ages and seed sown on November 29 produced tallest plant all over the ages. Interaction effects also indicated that wheat sown on November 29 resulted tallest plants in BARI Gom-24 after 45 days after sowing (DAS) up to harvest whereas, December 04 sown wheat produced the shortest plant in BARI Gom-28 from 75 DAS up to harvest. Baloch *et al.* (2010) reported that plant height of wheat differed significantly by planting time although they obtained tallest plant from October 25 and November 10 but decreased subsequently with successive sowing dates. Madhu *et al*. (2018) obtained significantly taller plant from November 15 sown BARI Gom-25. Thus the results of the present investigation are fairly in agreement with those of other workers who have found that plant height significantly decreased with delayed sowing (Hussain *et al*. 2008, Baloch *et al.* 2010, Madhu *et al*. 2018).

Findings revealed that foliar spray of NAA and N-fertilizer had mostly stimulatory responses on plant height where, full dose of N-fertilizer without foliar NAA produced maximum plant height throughout the ages. However, seed soaking with 10 ppm NAA in combination with 75% of the recommended N-fertilizer produced taller plant than all other treatments with few exceptions. Findings also revealed that late sown wheat produced comparatively taller plant than timely sown. Alam *et al.* (2002) obtained increased plant height of Soghat variety and decreased in Sarsabz and S-232 varieties of wheat due to 10, 20 and 30 ppm NAA application. Bakhsh *et al.* (2011) found tallest rice plant with 90 ml/ha NAA application. Jahan and Adam (2013) recorded tallest plant of BARI Gom-26 from 75 mg/L NAA treatment starting from 35 days after spray up to harvest. They also recorded increased plant height from 25 and 50 ppm NAA at early stage of growth. However, Jahan and Adam (2011) found both stimulatory and retarding effects of NAA on plant height of two varieties of rice. Application of 25 and 50 ppm NAA in combination with 50% of N-fertilizer produced taller plant than full dose of N-fertilizer in BARI Gom-26 (Islam and Jahan 2016a).

Increases in plant height following NAA application have also been reported in different plants by many investigators (Yadava and Sreenath 1975, Kelaiya *et al.* 1991, Rao 1993, Uddin *et al.* 1994, Lakshmamma and Rao 1996). Decreases in plant height following NAA application are also available (Setia *et al.* 1992, Klasa *et al*. 1996). However depending on the concentrations of NAA, Ullah *et al*. (2007) found both increases as well as decreases in plant height of cowpea. Thus the present results are in agreement with those of other workers who have observed that height of plants may increase or decrease depending on the sowing time, concentration of NAA and dose of N-fertilizer. The increase in plant height could be due to either increase in the number of cells or due to increase in size of cells or due to both (Mallik and Fattah 1974).

Sowing time had marked effect on the number of tillers per plant and the maximum number was obtained from November 15 sown wheat. Interaction effect showed that seeds sown on November 15 produced the highest number of tillers per plants in BARI Gom-25 but with few exceptions. Baloch *et al*. (2010) obtained maximum number of tillers per plant from October 25 and November 10 sown wheat but decreased subsequently with successive sowing dates. Jahan and Adam (2015) recorded significantly maximum number of tillers per plant of BARI Gom-25 from November 14 sown wheat. Madhu *et al*. (2018) also reported that November 15 sown BARI Gom-25 produced significantly maximum number of tillers per plant. Results indicated that number of tillers per plant decreased significantly beyond optimum sowing time and are fully in agreement with the findings of previous workers (Ejaz *et al*. 2002, Shivani *et al.* 2003, Baloch *et al*. 2010, Jahan and Adam 2015, Madhu *et al*. 2018).

Foliar application of NAA had non-significant responses on the number of tillers per plant of wheat whereas, higher doses of N-fertilizer produced higher number of tillers per plant all over the ages. Spraying 20 ppm NAA in combination with full doses of N-fertilizer although produced higher number of tillers per plant than all other combination treatments but statistically at par to many treatments including 20 ppm in combination with 25% N-fertilizer. Seed soaking with 10 ppm NAA in combination with 75% N-fertilizer resulted maximum number of tillers per plant throughout the ages at both timely and late sown condition. Results also revealed that timely sown wheat produced higher number of tillers per plant than those of late sown wheat although statistically at par with full dose of N-fertilizer alone and in combination with 10 ppm seed soaking treatment. By applying 10, 20 and 30 ppm NAA, Alam *et al.* (2002) reported increased number of tillers per plant in Sarsabz variety and decreased in Soghat and S-232 varieties of wheat. Jahan and Adam (2013) obtained increased number of tillers per plant following 25 and 50 ppm and decreased due to 75 and 100 ppm in BARI Gom-26. The beneficial effect of spraying NAA have also been reported by Chaudhuri *et al.* (1980) on rice and Mona *et al.* (2013) on barley. Islam and Jahan (2016a) found significant promotive effect of foliar NAA in combination with N-fertilizer on the number of tillers per plant of BARI Gom-26 where, 25 ppm NAA in combination with 50% N-fertilizer produced maximum value after 15 DAS. Thus the findings of the present study on the number of tillers per plant of wheat plants are in conformity with the findings of many workers.

Number of leaves per plant was influenced both significantly and non-significantly by different varieties and November 15 sown wheat produced significantly maximum number of leaves per plant at most of the ages. Outcome showed that November 15 sown wheat resulted highest number of leaves per plant in BARI Gom-25 throughout the ages but with few exceptions. This results are in accord with the findings of Jahan and Adam (2015) where they found maximum number of leaves per plant from November 14 sown BARI Gom-25 at most of the ages.

Findings showed that NAA as foliar spray had mostly non-significant responses on leaves of BARI Gom-25 but different levels of N-fertilizers produced significantly higher number of leaves per plant at most of the ages. Number of leaves per plant at harvest noted from full dose of N-fertilizer without any NAA was significantly higher than all other combinations except 75% N-fertilizer without NAA. During final experiment, seed soaking with 10 ppm NAA in combination with 75% N-fertilizer resulted higher number of leaves per plant in majority of cases of both sowing time but with few exceptions. Findings of the present investigation also indicated that seed soaking treatments were much effective for producing higher number of leaves than foliar spray treatment. The findings of the present study about the number of leaves per plant are in agreement with the findings of a number of workers. By applying NAA, Harsharn and Gill (1985) found significant increase on the number of leaves per plant in late sown wheat and barley. Jahan and Adam (2013) obtained increased number of leaves in BARI Gom-26 following 25 and 50 ppm and decreased over 50 ppm NAA application. Islam and Jahan (2016a) recorded higher number of leaves of BARI Gom-26 following combined application of NAA and N-fertilizer where, the maximum value was due to 25 ppm in combination with 50% N-fertilizer with both significant and non-significant variations.

Stimulatory effects of NAA on producing higher number of leaves have also been reported in rice by other researchers (Chaudhuri *et al*. 1980, Bnu and Huang 1980, Jahan and Adam 2011). However, both increases and decreases in number of leaves of maize following NAA applications have been reported by Akter (2010). In addition, combined treatments of NAA and N-fertilizer had both stimulatory and retarding effects on the number of maize leaves (Akter 2016).

Total dry matter (TDM) of crop is the output of net photosynthesis. It is mostly dependent on the size of the photosynthetic system or its activity as well as the length of its growth period during which photosynthesis continues (Watson 1947). During the present investigation, seeds sown on November 15 resulted highest TDM per plant in BARI Gom-25 at all ages and varied significantly in majority of cases. Supporting reports are very scanty regarding the effect of sowing time on this aspect. However, Hussain *et al*. (2008) found significantly higher biological yield from October 25 sown wheat cultivar than those of November 25 and December 25.

The TDM per plant were positively influenced following application of foliar NAA and N-fertilizer and also by their combinations at most ages of plants. Application of 20 ppm NAA in combination with full doses of fertilizer although resulted maximum TDM per plant but statistically not different from 20 ppm NAA in combination with 25% fertilizer dose at most cases. Findings also indicated that this combination (20 ppm NAA in combination with 25% fertilizer) resulted higher TDM than full dose of fertilizer alone. From the results of the final experiment (Experiment 4) it is evident that seed soaking treatment was more effective than foliar spray treatment and seed soaking with 10 ppm NAA in combination with 75%

N-fertilizer produced significantly higher TDM per plant both at timely and late sown condition. By applying NAA, Alam *et al*. (2002) found better results with 20 ppm in straw yield of three cultivars of wheat. Akter (2010) recorded significant increases in dry weight of maize at harvest due to NAA application. However, same concentration of NAA had stimulatory effects on BRRI Dhan-29 whereas, retarding effect on BRRI Dhan-50 (Adam 2010). The results are also in compliance to the findings of many other researches. Karim and Fattah (2007) obtained maximum dry matter per plant from 20 ppm NAA where dry matter tended to decrease with further increase in the concentration. Ullah *et al*. (2007) found that dry matter per plant of cowpea increased with increasing concentrations of NAA but up to 50 ppm. The stimulatory effect of NAA on total biomass have also been reported in black gram (Saxena 1994, Lakshmamma and Rao 1996), fiber hemp (Geel *et al*. 1994), cotton (Pothiraj *et al.* 1995), potato (Ahmed and Tahir 1995, Puste and Kundo 1995), green gram (Patel and Saxena 1994, Kalita *et al*. 1995).

The final yield of wheat is found as a function of several growth and yield attributing characters. Different researchers working with various crop plants have given importance on different yield contributing characters.

Results of experiment 1 indicated that sowing time had significant influences on the number of effective tillers (spikes) per plant where, November 15 sown BARI Gom-25 resulted significantly higher number of effective tillers per plant with few exceptions. Jahan and Adam (2015) and Madhu *et al.* (2018) also obtained similar results in the number of effective tillers per plant of BARI Gom-25. However, Shahzad *et al*. (2007) reported that wheat sown on December produced significantly higher number of productive tillers than sown on November. Hussain *et al*. (2008) observed that number of fertile tillers decreased linearly with successive delay in sowing from October 25 to December 25. Thus the outcome on the number of effective tillers per plant are fully in agreement with the findings of previous workers.

Foliar application of NAA, N-fertilizers as well as their combinations produced higher number of effective tillers per plant in most of the case. Combination of 20 ppm NAA and full dose of N-fertilizer although resulted maximum number of effective tillers per plant but statistically identical to many other combination treatments with lower doses of fertilizer including 20 ppm in combination with 25% N-level. Findings revealed that NAA as seed soaking treatments were more useful in producing higher number of effective tillers per plant than foliar spray treatment. At both sowing condition, seed soaking with 10 ppm NAA in combination with 75% N-fertilizer resulted significantly higher number of effective tillers per plant than all other treatments although statistically at par with full dose of N-fertilizer alone and 10 ppm NAA in combination with full dose of N-fertilizer treatments. However, timely sown wheat produced better stimulations than late sown. Orsi and Tallarico (1983) and Sing and Gill (1985) found that application of NAA had significant effect on the number of ear bearing tiller in late sown wheat and barley. Akter (2010) on maize, Bakhsh *et al.* (2011) on rice and Mona *et al.* (2013) on barley also reported about beneficial effect of NAA. However, number of effective tillers per plant of BARI Gom-26 was affected both positively and negatively depending on the concentration of NAA (Jahan and Adam 2013). Pronounced effects of NAA as foliar or seed soaking treatments had also been reported by a number of workers in different crops plants (Sing *et al.* 1972 on pea, Bangal *et al.* 1982 on gram, Deshai and Deore 1985 on cowpea, Katageri and Sheelvantar 1985 on chickpea, Kelaiya *et al.* 1991 on ground-nut, Kar *et al.* 1993 on tomato, Uddin *et al.* 1994 on lablab bean, Kalita *et al.* 1995 on green gram, Nowak *et al.* 1997 on field bean, Rao and Narayanan 1998 on pigeon pea).

Islam and Jahan (2016a) reported that combined application of NAA and N-fertilizer resulted significantly higher number of effective tillers per plant in BARI Gom-26 where, the maximum value was recorded from 25 ppm NAA in combination with 75% N-fertilizer. Combination of NAA and N-fertilizer treatments had similar trend in maize plants with few exceptions (Akter 2016).

Number of non-effective tillers per plant was influenced non-significantly by variety and sowing time although their combinations had both significant and non-significant effect on this trait. Seeds of BARI Gom-23 sown on November 22 produced significantly higher number of non-effective tillers per plant but statistically identical to BARI Gom-23 and BARI Gom-28 sown on November 15. However, the least number of non-effective tillers per plant was recorded from November 29 sown BARI Gom-27. Previous report is unavailable on the effect of sowing time on non-effective tillers per plant of wheat.

Foliar spraying with NAA, N-fertilizer as well as their combinations had non-significant responses on the number of non-effective tillers per plant. However, seed soaking with 10 ppm NAA in combination with various N-levels had better stimulations than foliar NAA and full doses of N-fertilizer treatments on this trait but with non-significant variations. The lowest number of non-effective tillers per plant was noted from 10 ppm NAA in combination with 25 and 75% N-levels at both sowing time. Jahan and Adam (2013) found significantly lower number of non-effective tillers from 50 ppm NAA in BARI Gom-26 whereas, rest of the treatments had statistically similar response to control. Although, Islam and Jahan (2016a) obtained lowest number of non-effective tillers per plant following the application of 25 ppm NAA but combinations of 25 and 50 ppm NAA at 50% of N-fertilizer had resulted higher number on this trait. Both increases as well as decreases in number of non-productive cobs of maize plants were observed by Akter (2016). Thus, the findings on the number of non-effective tillers per plant are conforming to the findings of previous workers.

Length of spike has indirect effect on yield through total number of filled grains. Results obtained from the present investigation revealed that wheat sown beyond optimum time reduced length of spike but with statistically identical value. Outcome of combined treatments showed that BARI Gom-24 sown on November 22 produced maximum length of spike but statistically identical to its rest of the sowing times. Baloch *et al*. (2010) obtained longest length of spike from October 25 and November 10 but with statistically similar value. Madhu *et al.* (2018) found significant decreases in length of spike beyond the time of November 15.

Both increases as well as decreases in length of spikes were observed following foliar application of NAA whereas, different levels of N-fertilizer produced better stimulation on this trait. Increases in length of spike following combined application of foliar NAA at varying N-fertilizer were observed from the present investigations with an exception. Foliar spray of 20 ppm NAA in combination with 25% N-fertilizer produced maximum length of spike than other treatments with significant variations in most of the cases. During the final experiment seed soaking with 10 ppm NAA in combination with 75% N-fertilizer although produced longest spike at both sowing time but were not statistically different from full dose of N-fertilizer and foliar spray of 20 ppm NAA in combination with 25% N-fertilizer.

Outcome of the present investigation are in agreement with the findings of previous workers. Length of earhead was unaffected following 10, 20 and 30 ppm NAA application in three varieties of wheat (Alam *et al.* 2002). Jahan and Adam (2013) obtained non-significantly higher length of spike following NAA application. Similar results of increases due to NAA application have also been found in maize (Akter 2010). However, same concentration of NAA had stimulating effects on a variety and retarding effect on another variety of rice plants (Adam and Jahan 2011). Increases in length of spike of BARI Gom-26 due to combined application of NAA and N-fertilizer were observed by Islam and Jahan (2016a). Akter (2016) found similar results of increases in cob length of maize following NAA in combination with various rates of N-fertilizer in majority of cases.

Seeds sown on November 15 produced significantly higher dry weight of spike than rest of the sowing time. Results indicated that due to combination treatment November 15 sown BARI Gom-25 produced significantly higher dry weight of spike. Earlier report regarding the effects of sowing time on this aspect is unavailable. The reasons for obtaining higher weight of spike might be due to proper light, temperature and prevailing environmental condition throughout the growing period which favours better growth of spikes with increased grain weight.

Dry weight of spikes were found to increase due to foliar application of NAA and N-fertilizer treatments. The maximum dry weight of spike was noted from seed soaking with 10 ppm NAA at 75% N-level both at timely and late sown condition but in case of timely sown wheat it was significantly higher than most of the treatments including full dose of N-fertilizer alone and any foliar spray treatments. By applying 20 and 30 ppm NAA, Alam *et al.* (2002) recorded higher dry weight per earhead in one variety of wheat whereas the same concentration had retarding effects on other two varieties of wheat. In addition Islam (2015) recorded better result from the interaction of 25 ppm NAA with 75% of the N-fertilizer than that obtained from NAA or N-fertilizer alone.

Similar results of increases as well as decreases in dry weight of panicle following NAA application has also been reported in two rice varieties (Adam 2010). But in case of maize, Akter (2010) found significant increases in dry weight of cob due to NAA application. Combinations of NAA and N-levels had also promoting effect on dry weight of tassel in most cases (Akter 2016). Thus the results of the current investigation are in conformity with the findings of preceding researchers.

Number of grains per spike is an important yield contributing characters and varies from variety to variety. Although it is genetically controlled, but environmental factors may influence number of grains per spike. The present studies indicated that number of grains per panicle and per plant were differently affected by different sowing time. Due to combined treatments BARI Gom-24 sown on November 29 produced significantly higher number of grains per plant than rest of the treatments with few exceptions whereas, in case of number of grains per plant the same results was obtained from November 15 sown BARI Gom-25. Hussain *et al*. (2008) reported that wheat sown on October 25 produced significantly greater number of grains per spike than that sown on December 25 but statistically alike to November 25 sown wheat. Jahan and Adam (2015) obtained the maximum number of grains per plant from November 24 sown BARI Gom-25 followed by November 14. Madhu *et al.* (2018) obtained significantly higher number of grains per spike from BARI Gom-25 sown on November 15. Thus the clarification of this research are in conformity with the findings of earlier workers.

Increases in number of grains per spike and per plant were obtained from foliar NAA and N-fertilizers in most of the cases. Interaction effects indicated that 20 ppm NAA in combination with 25% N-level produced maximum number of grains per spike however, in case of number of grains per plant it was found from 20 ppm NAA with full dose of fertilizer but both were statistically identical to each others. During the fourth experiment, seed soaking with 10 ppm NAA in combination with 75% N-level had resulted significantly higher number of grains per plant than most of the treatments including full dose of fertilizer and foliar spray treatments at both timely and late sown condition. Islam and Jahan (2016a) obtained maximum number of grains per spike and per plant from 25 ppm NAA in combination with 75 % of the N-fertilizer which was also higher than those of recommended dose of N-fertilizer. Akter (2016) recorded higher number of kernels due to all combined application of NAA and N-fertilizers in maize. Bakhsh *et al.* (2011) and Adam and Jahan (2011) also reported about affirmative effect of NAA in producing higher number grains per panicle in rice plants. Thus the findings of the present study are in accord with the findings of the earlier studies of different investigators.

Weight of 1000-grain significantly decreased beyond optimum sowing time and BARI Gom-25 sown on November 15 produced significantly maximum 1000-grain weight. Jahan and Adam (2015) recorded maximum 1000-grain weight from November 14 sown BARI Gom-25. Madhu *et al.* (2018) also found significantly highest 1000-grain weight from November 15 sown wheat. Findings obtained during the present investigation are also in conformity with the findings of various workers who have reported that 1000-grain weight of wheat reduced significantly with delayed sowing (Abdullah *et al*. 2007, Hussain *et al*. 2008, Baloch *et al*. 2010, Jahan and Adam 2015, Madhu *et al.* 2018).

Although foliar spray of NAA and N-fertilizer alone had no beneficial effect on 1000-grain weight of wheat but combination treatments had positive influences with few exceptions. Results revealed that timely sown wheat produced better stimulation than late sown condition whereas, seed soaking with 10 ppm NAA produced better stimulation in both sowing time. In earlier studies, it was also found that 1000-grain weight of wheat increased both significantly and non-significantly following NAA treatments (Chen *et al.* 1984, Harsharn and Gill 1985, Jahan and Adam 2013). Positive influences of NAA with different concentrations on this yield parameter were also reported in maize (Akter 2010) and rice (Bakhsh *et al.* 2011). However, decreases in 1000-grain weight due to NAA application was reported by Adam and Jahan (2011) in two varieties of rice.

Increases in 1000-grain weight was also reported by many workers on different crops. Seeds soaking with 10 ppm NAA solution increased 1000-grain weight of pea (Sing *et al.* 1972). Similar results of increases due to NAA application have also been reported by other workers on different crop plants (Kaul *et al.* 1976, Singh and Sharma 1982, Bangal *et al.* 1983, Suty 1984, Ravikumar and Kulkarni 1988, Sharma and Sharma 1989, Kelaiya *et al.* 1991, Upadhayay *et al.* 1993). However, Ullah *et al.* (2007) obtained both increases as well as decreases in 1000-seed weight due to NAA treatments.

Islam and Jahan (2016a) recorded both positive and negative influences following combined application of NAA and N-fertilizer treatments where, 25 ppm NAA in combination with 75% N-fertilizer produced maximum 1000-grain weight. However, Akter (2016) recorded maximum 1000-grain weight from 50 ppm NAA in combination with 50% higher rate of N-fertilizer in maize. Thus the findings of the present study are in conformity with those of previous workers.

Yield is the result of physiological and biochemical interactions. It was evident from experiment 1 carried out during 2014-2015 season that yield per plant and per hectare obtained from different varieties were dissimilar. It was also evident that sowing time had significant influences on wheat and November 15 sown BARI Gom-25 produced significantly highest yield per plant and per hectare whereas, the minimum was noted from BARI Gom-27 sown on December 04. Shah and Akmal (2002) reported that different varieties of wheat responded differently on different sowing dates. Akhtar *et al.* (2006) showed that regardless of varieties or cultivars, better yields were obtained when wheat was sown after November 15 and before November 30. Ali *et al*. (2010) recorded significantly higher grain yield from November 10 sown wheat followed by November 20. Baloch *et al*. (2010) obtained statistically identical grain yield from October 25 and November 10 sown wheat. Similar results in yield per plant of wheat crops was also obtained by Hussain *et al*. (2008). Jahan and Adam (2015) reported that November 14 and 24 sown BARI Gom-25 produced statistically similar yield per plant. Madhu *et al.* (2018) reported that BARI Gom-25 produced maximum yield although statistically at par to BARI Gom-26 but significantly higher than rest of the varieties. Findings also indicated that yield per plant decreased subsequently with successive sowing dates in most cases and are inconsistence with the outcome of above mentioned researchers.

During the experiment 2, yield per plant and per hectare were positively influenced by most of the foliar NAA treatments and different N-levels. Results revealed that combination of NAA and N-fertilizer treatments produced higher yield than the control where, 20 ppm in combination with full dose of N-fertilizer produced maximum value but statistically not different from some lower doses of N-fertilizers including 20 ppm in combination with 25% fertilizer. Results obtained from experiment 3 also revealed that seed soaking with 10 ppm NAA in combination with 75% N-fertilizer produced maximum yield per plant and per hectare both at timely and late sown condition where, better stimulation was observed from timely sown wheat. In case of timely sown wheat, seed soaking with 10 ppm NAA in combination with 75% N-dose produced significantly higher yield than full dose of N-fertilizer alone and foliar spray treatments .

The stimulation of yield of wheat as a results of NAA application, observed during this investigation corresponds with reports on various cereal crops *viz*. rice (Misra and Sahu 1957, Chaudhuri *et al.* 1980, Sahu and Murty 1981), sorghum (Thakre 1985, Tulsa-Ram *et al.* 1997), maize (Muthukumar *et al.* 2005). But the effective concentration of NAA varied from crop to crop and even between varieties of the same crop. Application of 20 ppm NAA had better response in enhancing grain yield of Sarsabz and S-232 varieties of wheat however, same concentration had retarding effect on Soghat variety. Both increases and decreases in yield per plant of BARI Gom-26 due to NAA application was also obtained by Jahan and Adam (2013).

Increases in yield due to NAA application has also been reported by many investigators on different crops *viz*. chickpea (Khan and Chowdhury 1976, Bangal *et al.* 1982, Katageri and Sheelvantar 1985, Upadhyay *et al.* 1993), cowpea (Deshai and Deore 1985, Borkar *et al.* 1991, Shinde *et al.* 1991, Jain *et al.* 1995, Shinde and Jhadav 1995, Singh and Sharma 1996), lentil (Setia *et al.* 1992), fibre hemp (Geel *et al.* 1994). potato (Ahmed and Tahir 1995, Puste and Kundo 1995), cotton (Pothiraj *et al*. 1995), black gram (Lakshmamma and Rao 1996), sesame (Tripathy *et al.* 1996), soybean (Deotale *et al.* 1998), pigeon pea (Rao and Narayanaa 1998), guava (Iqbal *et al.* 2009), *Costata persimmon* (Kassem *et al.* (2010).

However, scanty information is available on the effect of NAA in combination with N-fertilizer on the yield of wheat plants. Islam and Jahan (2016a) found significant influences of NAA and N-fertilizer treatments where, the maximum yield was recorded from 25 ppm NAA in combination with 75% N-fertilizer application. Similar results of increases in grain yield following combined application of NAA and N-fertilizer was also reported by Akter (2016) in maize.

Harvest Index is positively correlated with yield. A high HI is desirable to get maximum benefit from the input. In experiment 1 of the present investigation, BARI Gom-25 produced maximum HI and was significantly higher than BARI Gom-27 whereas, wheat sown on November 15 resulted significantly higher HI than that sown on December 04. In case of combined treatment, BARI Gom-28 sown on November 29 produced the highest HI but statistically identical to almost all varieties sown on November 15. Usually wheat sown on optimum time produced higher HI but it is variable depending on varieties, location and climatic conditions. Findings of the present study are in agreement with the outcome of Hussain *et al*. (2008) and Jahan and Adam (2015) on wheat.

During the present investigation both increases and decreases in HI of BARI Gom-25 were obtained from NAA treatments, N-fertilizer levels and their combination effects. Findings also showed that although seed soaking treatments produced better stimulation than foliar spray and also full dose of N-fertilizer treatments both at timely and late sown condition but were statistically indistinguishable to each other. Jahan and Adam (2013) reported similar results of increases as well as decreases in HI of wheat following NAA application. Islam and Jahan (2016a) found maximum HI from 25 ppm NAA treatment in combination with 75% N-fertilizer. Application of NAA at varying N-levels produced higher HI in maize (Akter 2016). Thus the findings of the present study are partially in accord with the findings of other workers.

Like the physiological parameters, different treatments have some effects on the biochemical parameters of the plant parts and also on the grain. In the present study, for experiment 2, 3 and 4 some biochemical parameters were investigated.

In plants, utilization of solar energy mainly depends on the relative amount and efficiency of the photosynthetic pigments. Chlorophyll content of leaf is an important factor for increasing or decreasing photosynthesis of any crop plant.

It was evident from experiment 2 carried out during 2015-2016 season that application of NAA, N-fertilizer and their combined treatments had both stimulatory and retarding effects on pigment content of leaves at different stages of BARI Gom-25. Findings also revealed that combined application of NAA and N-fertilizer had not any general trend on leaf pigments and the maximum value in pigment content was obtained depending on the concentrations of NAA, fertilizer dose and plant growth stages. Results of experiment 3 and 4 indicated that seed soaking with 10 ppm NAA in combination with full dose of N-fertilizer had better influences in pigment contents of leaves at different stages but with few exceptions. Findings also indicated that timely sown wheat produced more pigments than late sown in majority of cases.

A number of investigators reported increases in chlorophyll contents of various plants following NAA applications (Jahan *et al.* 1992, Lakshmamma and Rao 1996, Chaudhuri *et al.* 1980, Singh and Gill 1985, Orsi and Tallarico 1983, Akter 2010). However, In BRRI Dhan-29, Jahan and Adam (2014) found increases in chlorophyll a (chl. a), chlorophyll b (chl. b) and carotenoids contents following NAA application at flowering and grain filling stages but decreases at tillering stage.

Report relating to the effect of NAA in combination with N-fertilizer on pigment content of wheat is scanty. Islam (2015) obtained significantly higher chl. a and chl. b content of leaves following NAA in combination with various N-levels at flowering and grain filling stages having few exceptions. However, combination of NAA and N-fertilizer had not produced any significant difference in carotenoids content of leaves. Application of NAA at varying N-level produced negative influences in pigment content of leaves at tassel initiation stage and both stimulatory and retarding effects at grain filling stage (Akter 2016). Thus the findings of the present investigation are in agreement with the results of previous workers.

Increases in nitrogen (N), phosphorus (P) and potassium (K) contents of shoot and root at different stages and grain at harvest of both timely and late sown BARI Gom-25 were observed in majority of cases. Findings of the present investigations are in agreement with the outcome of many previous researchers. The NPK contents of fenugreek were positively influenced by NAA application (Purbey and Sen 2007). Similar results of increases in NPK contents of shoot and root was obtained by Adam (2010) in two varieties of rice. By applying NAA, Adam *et al.* (2012) recorded both stimulatory and retarding effect on NPK contents of grain. Application of NAA at varying N-levels had mostly stimulatory effect on NPK contents of shoot and root of BARI Gom-26 (Islam 2015). Islam and Jahan (2016b) showed that combined application of NAA and N-fertilizer had beneficial effect on NPK contents in grain of BARI Gom-26.

Higher NPK uptake by shoot and root at flowering and grain filling stage of both timely and late sown BARI Gom-25 were observed following combined application of NAA and N-fertilizer. However, increases as well as decreases in NPK uptake by shoot, root and grain were obtained at harvest. Finding also revealed that seed soaking with 10 ppm NAA in combination with 75% N-fertilizer had enhanced uptake capacity at flowering stage and at harvest. Purbey and Sen (2007) recorded higher NPK uptake due to NAA application in Fenugreek. Application of NAA had pronounced effect on NPK contents of maize (Akter 2010) and uptake by rice (Adam *et al.* 2012). By applying NAA at varying N-levels, Islam and Jahan (2016b) obtained higher N and K uptake by shoot and root both at flowering and grain filling stages of BARI Gom-26. Results obtained in case of P uptake by shoot and root and NPK uptake by grain are also in agreement to the findings of Islam and Jahan (2016b) in BARI Gom-26.

Application of NAA at various N-levels had resulted significantly higher nitrogen use efficiency (NUE) than full dose of N-fertilizer in both sowing time with an exception. Outcome of the present investigation also revealed the total NUE at flowering, grain filling and at harvest were recorded highest from seed soaking with 10 ppm NAA at 75% N-level, seed soaking with 10 ppm NAA at 25% N-level and foliar spray of 20 ppm in combination with 25% N-level respectively where, timely sown wheat had higher NUE than late sown condition.

It is thought that one of the ways by which growth regulators influence the growth and development of plants is by stimulating the uptake of nutrients through increased growth of the root system. Since NPK plays an important role in respiration, photosynthesis and nitrogen metabolism, growth regulator action may involve an increase in the above metabolic activities due to increased uptake of NPK. Increased uptake of NPK is a reflection of dry matter yield of wheat. The lower uptake of any nutrient may be because of less nutrient in the plant sample and also because of total dry matter production.

Earlier studies of Islam and Jahan (2016b) showed that NAA in combination with various N-levels had significant variations on NUE of root at flowering stage and shoot at grain filling stage. They found highest NUE of shoot and total plant from 50 ppm NAA in combination with 50% N-fertilizer at flowering stage however, at grain filling stage the maximum NUE of root was obtained from 25 ppm NAA at 50% N-fertilizer level. Thus the stimulating effect of NAA at various N-level on NUE of wheat is fairly in compliance to the findings of present study.

Three treatments *viz.* control, 100% of recommended (full) dose of N-fertilizer and seed soaking with 10 ppm NAA in combination with 75% N-fertilizer (best performed treatment) were selected for comparative analysis among nutritional parameters, amino acid contents, enzyme activities and mineral contents of grain obtained from timely sown wheat.

Carbohydrate content in grain significantly decreased following both full dose of N-fertilizer and seed soaking with 10 ppm NAA in combination with 75% N-fertilizer treatments. Decreases in carbohydrate content in grain following NAA application has also been reported by Deshai and Khanvilkar (1997) on Bangal gram, Olaiya *et al.* (2010) on tomato and Noor *et al*. (2017) on French bean. However, Akter

(2010) on maize and Jahan and Adam (2014) on rice found stimulative effect of NAA in carbohydrate content of grain. But no report is available relating to the effect of NAA in combination with N-fertilizer on this aspect.

Seed soaking with 10 ppm NAA in combination with 75% N-fertilizer produced significantly maximum protein content in grain. Previous investigations also revealed inducing effects of NAA on different crops *viz*. rice (Jahan and Adam 2014), chickpea (Singh and Jain 1982, Dhingra *et al.* 1995, Karim *et al.* 2006), bitter gourd (Jahan *et al.* 1992), black gram (Lakshmamma and Rao 1996), tomato (Olaiya *et al*. (2010), French bean (Noor *et al*. 2017). But report regarding the effect of NAA in combination with N-fertilizer is inadequate. However, Islam (2015) obtained non-significantly higher protein content in grain of BARI Gom-26 following NAA in combination with N-fertilizer. He found maximum protein content from 25 ppm NAA in combination with 75% N-level. Thus the findings of the present research are in harmony with the outcome of earlier research.

Fat content in grain significantly influenced by seed soaking with 10 ppm NAA in combination with 75% N-level but statistically not different from full dose of N-fertilizer. Although previous report relating to the combined effects of NAA and fertilizer is unavailable but different investigators have found profound responses of NAA depending on concentration and types of crop plants (Karim *et al.* 2006, Ullah 2006, Akter 2010, Olaiya *et al*. 2010, Jahan and Adam 2014, Noor *et al*. 2017).

Starch content of grain following best performed treatment was significantly higher than control and full dose of N-fertilizer. But no previous report is obtainable regarding the positive influence of NAA alone or in combination on this aspect. Results revealed that moisture content of grains significantly decreased following both full dose of N-fertilizer and best performed treatments. Decreases in moisture content of grain due to NAA treatments were also reported by Akter (2010) on maize and Jahan and Adam (2014) on rice.

Significantly higher amount of crude fibre content of grain was obtained from full dose of N-fertilizer and seed soaking with 10 ppm NAA in combination with 75%

N-level treatments. Karim *et al.* (2006) obtained increased crude fibre content of dry seeds of chickpea following 10 ppm NAA. Application of NAA treatments had also resulted significantly higher crude fibre content in fresh pod of French bean but up to a certain concentration (Noor *et al*. 2017). Thus the findings of present research are in accord with the findings of previous workers.

Seed soaking with 10 ppm NAA in combination with 75% N-level also produced significantly higher ash content than control and full dose of N-fertilizer. Increases in ash content due to NAA application has also been reported by Karim *et al.* (2006) on chickpea, Olaiya *et al*. (2010) on tomato and Noor *et al*. (2017) on French bean. But no report is available following combined application of NAA and N-fertilizer on this feature.

Total sugar content of grain was recorded significantly maximum from seed soaking with 10 ppm NAA in combination with 75% N-level. Earlier findings of Upadhyay *et al.* (1993) on chickpea and Ibrahim *et al.* (2007) on Faba bean also revealed stimulating response of NAA in increasing total sugar content in seed. But no report is yet available on this aspect.

Results of present study revealed that the best performed treatment had resulted significantly higher reducing sugar content in grain than control and full dose of N-fertilizer. Jahan *et al.* (1992) showed that NAA treatment had inducing effect on reducing sugar content of bitter gourd fruit at edible stage.

During the present investigation amino acids *viz*. aspartic acid, serine, glutamic acid, glycine, alanine, valine, isoleucine, leucine, tyrosine, histidine, lysine and arginine contents were recorded maximum from seed soaking with 10 ppm NAA in combination with 75% N-level. Findings also indicated that aspartic acid, glutamic acid, leucine, lysine and arginine contents following best performed treatment were significantly higher than control and full dose of N-fertilizer. Karim *et al*. (2006) obtained similar results of increases in aspartic acid, arginine, lysine, leucine, isoleucine, phenylalanine, serine, glycine and alanine, valine, tyrosine and threonine contents of chickpea following 10 ppm NAA. The results of the present investigation are also consistent with the findings of Dhingra *et al.* (1995), Deshai and Khanvilkar (1997), Ullah *et al*. (2011) and Noor *et al.* (2017) where they have reported that amino acid contents of grain increased following NAA application.

Findings revealed that seed soaking with 10 ppm NAA at 75% N-level had significantly higher α-amylase activity than full dose of N-fertilizer. Protease activity in grain although recorded maximum from this treatment but statistically at par to full dose of N-fertilizer. Very limited reports have been found relating to the effects of plant growth regulators on amylase and protease activities of wheat grain. El-Feky and Abo-Hamad (2014) found gradual increases in both amylase and protease activities following Brassinolide application.

Results obtained from the present study showed that the best performed treatment although produced increased N, K, Fe and Ca contents in grain but statistically not different from full dose of N-fertilizer. Results also showed that P and Zn contents of grain were recorded maximum from full dose of N-fertilizer and was significantly higher in case of Zn content. Findings of previous studies revealed that application of NAA had stimulatory effects on NPK contents of grain in Fenugreek (Purbey and Sen 2007) and maize (Akter 2010). Depending on the concentrations of NAA and variety of rice plant, Adam *et al.* (2012) found both stimulatory and retarding responses on NPK contents of grain. Combined application of NAA at varying N-levels had beneficial effect on NPK contents of wheat grain (Islam and Jahan 2016b). Thus the present findings are in partial accordance with those of previous workers. However, no report is available on Fe, Ca and Zn contents of wheat grain.

The overall findings of the present investigation presented herein are consistent with the view that when applied at proper dose to a plant at the correct ontogenic stage, a growth regulator may bring stimulation of vegetative parts of a plant and thus may ultimately lead to increase in yield of the plant. Thus, it is quite clear from the studies that NAA which cost very little have got the potentiality to increase yields of a good number of crops including wheat. In addition, results presented herein are in accord with the findings of a number of researchers in that the change in vegetative and reproductive phases of plants following application of NAA are associated with some physiological and biochemical changes in the plant body.

In Bangladesh, it is the high time to think about balanced fertilizer practices because it is environment friendly. There is a tremendous prospect of using NAA treatments in our country because of its low cost; and particularly seed soaking treatment because farmers already use seed soaking practice for better germination. Thus seed soaking with NAA will help to reduce the cost of N-fertilizer. For example, for wheat, the requirement for urea is 220 kg/ha, the cost of which comes to Taka 3520 (16 Taka/kg urea). By seed soaking with NAA, it has been observed in the present study that this requirement could be almost 25% less for obtaining the same yield. This means that the urea requirement will be about 165 kg/ha, the cost of which comes to 2640 Taka which is about 880 Taka less. It need to be mentioned here that the cost of NAA is very low; approximately 100 Taka is required for soaking seeds per hectare, which is insignificant in comparison to the cost of fertilizer. So, by seed soaking with 10 ppm NAA and applying 25% less urea, the yield of wheat could be increased up to 24.80%.

From the cost benefit analysis, it is revealed that the total price of wheat obtained from recommended (full) dose of N-fertilizer treatment in per hectare area is Taka 77,500 (25 Taka/kg wheat) whereas, approximately Taka 95,000 could be obtained from seed soaking with 10 ppm NAA at 75% N-level treatments. So, the total benefit obtained from the suggestive treatment is Taka 17,500/ha.

The best performed treatment had also significant beneficial effect on different biochemical components *viz.* leaf pigments, nutrient uptake, nitrogen use efficiency, nutritional value, enzyme activities, amino acid and mineral contents. By reducing the demand of nitrogen fertilizer up to 25%, this best performed treatment not only increase the yield of wheat but remarkably improved the quality of grain. On the other hand, The United States Environmental Protection Agency has declared Naphthalene acetic acid, its salts, ester and acetamide as environmentally safe products. Thus, use of NAA in soaking seeds is obviously economically advantageous and also environment friendly.

In proposing physiological and biochemical basis for the stimulation of growth and yield following NAA treatments, the following points may be emphasized; that the stimulation of vegetative parts gave a larger amount of photosynthate and later could have been utilized for the biosynthesis of cell constituents. Higher amount of photosynthate would also serve as substrate for the higher rate of respiration and other chemical processes. Stimulated rate of vegetative growth also brought about changes in the endogenous chemical levels and possibly that of endogenous growth regulators and as a result of which the reproductive growth rate was stimulated and consequently there was increase in yield.

Different factors *viz.* temperature, relative humidity, wind speed, sunshine hour and solar radiation have individual effect on crop production. In the present research the crop was grown in different sowing time and, therefore, fluctuating variations of all these factors influenced the crop growth and yield.

Thus, outcome obtained during the present investigation on the effect of Naphthalene acetic acid and sowing time on yield, fertilizer use efficiency (FUE) and grain quality of wheat plant may be helpful in the prevailing situation of FUE aspects in Bangladesh.

CONCLUSION

Investigations carried out throughout the world has conclusively proved the stimulatory effect of NAA on growth, yield, physiological and biochemical parameters of a number of different field and horticultural crop plants. In Bangladesh NAA have also found to be stimulative on different crops including cereals. However, the nature and the magnitude of the responses were different for different plants depending on different concentrations and also methods of treatments of the chemical.

Findings of the present research also indicated that the use of NAA not only reduces the nitrogen requirement but also enhances NUE. The NAA treated plants had increased plant growth, pigment content and nutrient uptake depending on nature and also on concentrations. Thus, a combination of these factors result in the increased photosynthetic capacity of treated plants and consequently grater amount of dry matter than necessary for vegetative growth, and which is used for grain filling. From physiological standpoint NAA stimulated physiological and biochemical processes which in turn enhanced effective growth components leading to higher yield.

Seed soaking with 10 ppm NAA at 25% less urea had not only resulted higher yield but also increased nutritional value, enzyme activities, amino acids and mineral contents of wheat grains. The stimulation of physiological and biochemical activities of wheat plants following NAA application, suggest that the activity of this chemical is mediated through different pathways of carbohydrate and nitrogen metabolism, which lead to enhanced growth and ultimately increases yield of treated plants. The NAA induced changes of growth of plants may also be due to its effect on nutrient absorption, distribution and uptake.

It is becoming increasingly evident that hormone do not act alone in isolated systems but in an interrelated manner in the plant as a whole. Plant growth and development are closely related to the concentration of some endogenous growth regulators viz. abscisic acid, gibberellins and indole acetic acid. It is possible that morphological changes induced by NAA could be because of its effect on endogenous levels of these three plant growth regulators. Thus the proportion of various hormones endogenously present may immensely affect the growth rate or subsequent differentiation pattern of the tissue in the complete organism, while the presence of both stimulatory and inhibitory hormones permits a precise control of many developmental activities in some cases.

Currently high yielding varieties (HYV) of wheat *viz.* BARI Gom-23, BARI Gom-24, BARI Gom-25, BARI Gom-26, BARI Gom-27 and BARI Gom-28 have extensively been used by farmers in our country. Among these varieties, BARI Gom-25 was selected as the best performing variety from experiment 1 and was used as plant material for experiment 2, 3 and 4. But, in the meantime some other HYVs of wheat were released by BARI and as a result, more research work in future using NAA on these varieties of wheat are required.

Moreover, Bangladesh has different soil and climatic zone. Therefore, field experiments should be carried out in different agroclimatic zones to confirm the outcome in improving the productivity of different varieties of wheat grown in Bangladesh with special emphasis on different doses of N-fertilizer and different concentrations of NAA to enable us to have a clear cut picture. At the end of which suggestions could be made on the beneficiary effect of the application of NAA towards increasing yield in important crops of Bangladesh in general and wheat in particular.

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Appendix 1: Meteorological data

Monthly average of minimum and maximum temperature, relative humidity and total rainfall at Dhaka City during the experimental period of 2014-2017.

Year	Month	Temperature ° C		Relative humidity (%)	Total rainfall (mm)
		Minimum	Maximum		
2014	October	24.0	32.2	72	49
	November	19.6	30.2	66	00
	December	15.0	24.5	77	00
2015	January	14.6	24.7	70	03
	February	17.0	28.4	63	17
	March	20.6	32.1	52	04
	April	23.3	32.8	68	166
	May	25.4	34.0	71	185
	June	26.6	32.7	77	375
	July	26.0	31.7	81	623
	August	26.9	32.6	79	395
	September	26.0	32.8	78	346
	October	24.1	32.3	73	51
	November	19.9	30.2	69	00
	December	16.2	25.9	68	01
2016	January	14.1	24.8	68	03
	February	19.0	29.8	63	13
	March	22.5	33.1	59	55
	April	26.9	35.1	72	55
	May	24.9	33.6	74	212
	June	27.0	33.9	75	212
	July	26.5	32.2	82	405
	August	26.8	33.2	77	171
	September	26.6	32.8	82	138
	October	25.2	33.0	74	76
	November	20.2	29.6	73	25
	December	17.0	27.7	72	00
2017	January	14.8	20.6	62	00
	February	17.5	23.6	57	02
	March	20.3	25.4	67	100
	April	23.9	28.4	72	228
	May	25.9	30.2	73	188
	June	26.5	29.8	80	414
	July	26.4	29.2	83	584
	August	26.7	29.7	83	544
	September	26.8	30.0	82	381
	October	24.8	28.4	79	412
	November	20.5	25.4	67	06
	December	17.0	21.9	76	33

Source: Yearbook of Agricultural Statistics 2017 (Bangladesh Meteorological Department)

Bangladesh J. Bot. **48**(1): 43-51, 2019 (March)

EFFECTS OF SOWING TIME ON GROWTH AND YIELD PERFORMANCE OF SIX HIGH YIELDING VARIETIES OF WHEAT (*TRITICUM AESTIVUM* L.)

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Keywords: Wheat, Variety, Sowing time, Growth, Yield performance

Abstract

A field experiment was conducted to evaluate the growth and yield performance of six high yielding varieties of wheat *viz.*, BARI Gom-23, BARI Gom-24, BARI Gom-25, BARI Gom-26, BARI Gom-27 and BARI Gom-28 in four sowing time. BARI Gom-24 sown on November 29 produced tallest plant after the age of 45 days with significant variations. Results also indicated that November 15 sown BARI Gom-25 resulted the highest number of tillers, leaves and total dry matter per plant throughout the growth ages with a few exceptions where dry matter produced at the age of 60, 75 and 90 days were significantly higher. Yield parameters *viz.*, number of grains per plant, dry weight of spike, 1000-grain weight, yield per plant, yield per hectare and harvest index were recorded maximum from BARI Gom-25. On the other hand, seeds sown on November 15 produced significantly higher value in all yield contributing characters except number of effective tillers and number of grains per spike. In case of combined treatments, November 15 sown wheat showed similar trend in majority of yield parameters of BARI Gom-25 where, dry weight of spike, 1000-grain weight, yield per plant and yield per hectare were significantly higher than rest of the treatments. Out of six varieties, BARI Gom-25 was the best performed variety. November 15 sown wheat had remarkable effects on yield attributes and yield of most of the varieties but beyond this time yield of wheat reduced significantly.

Introduction

Wheat (*Triticum aestivum* L.) is the world's largest cereal crop and consumed every day in almost everyone's life. The International Food Policy Research Institute (IFPRI) projections indicate that the world demand for wheat will rise to 775 million metric tons by 2020, and 60% in total by 2050 and at the same time, climate change-induced temperature increases are likely to reduce wheat production in developing countries where around 66% of all wheat is produced (Rosegrant and Agcaoili 2010). In Bangladesh, it is the second major cereal crop after rice, but rice alone is no more capable of providing balanced and nutritious food for the human, poultry and livestock. At present about 1.4 million metric tons of wheat is being produced in Bangladesh against the national demand of 5.6 million metric tons and the country needs to import about 4.5 million metric tons wheat every year (Azad *et al.* 2017).

Increasing wheat production is a big challenge for Bangladesh. Among the various agronomic techniques, selection of high yielding variety and optimum sowing time is the easiest way to achieve desired yield because different varieties responded differently for the genotypic characters, input requirement, growth process and the prevailing environment during growing season. Optimum time for wheat is very important due to its own definite requirements for temperature and light for emergence, growth and flowering (Dabre *et al.* 1993). On the other hand, late sowing of wheat is a major problem in the rice wheat areas of Asia (Hobs and Gupta 2002). Delayed sowing suppressed the yield, caused by reduction in the yield contributing traits like number of tillers, number of grains per spike and grain yield (Ansary *et al.* 1989). After optimum sowing time, production of wheat decreases about 18 kg per hectare for each day (Saifuzzaman *et al.* 2010).

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Results of several investigations from abroad showed that sowing time had marked effect on growth and yield of different varieties of wheat (Shah and Akmal 2002, Subhan *et al*. 2004, Akhtar *et al.* 2006, Abdullah *et al.* 2007, Shahzad *et al*. 2007, Ali *et al*. 2010, Baloch *et al.* 2010). But, in Bangladesh very little number of reports are available on wheat in relation to cultural method and varietal effect (Rahman *et al.* 2010) and sowing time (Rashid *et al.* 2004, Jahan and Adam 2015). Therefore, an attempt was taken for the selection of the best performed variety of wheat in relation to different sowing time.

Materials and Methods

A field experiment was conducted at the Botanical Garden of the Department of Botany, University of Dhaka during 2014 - 2015 and was laid out in randomized block design with four replications. Experimental field was prepared conventionally where the total area was 98.56 m^2 (17.60 m × 5.60 m). Nitrogen, phosphorus and potassium content of experimental soil were determined by Micro-Kjeldalh's method (Marr and Cresser 1983), ascorbic acid blue colour method (Murphy and Riley 1962) and flame photometer (Jackson 1973), respectively. Soil contains low amount of nitrogen, very high amount of phosphorus and very low amount of potassium. Fertilizers *viz.*, urea, muriate of potash, gypsum and boric acid were applied at doses recommended by Fertilizer Recommendation Guide (2012). Two-thirds of urea and full of the other fertilizers were applied as basal dose during final land preparation. Cow-dung was also mixed homogenously as recommended by Fertilizer Recommendation Guide (2012). The remaining urea was applied immediately after the first irrigation. Seeds of six high yielding varieties of wheat *viz.*, BARI Gom-23(V_1), BARI Gom-24(V_2), BARI Gom-25(V_3), BARI Gom-26(V_4), BARI Gom-27(V_5) and BARI Gom-28(V_6) were collected from BARI, Joydebpur, Gazipur and were sterilized with 0.5% calcium hypochlorite before sowing. Seeds were sown in lines 20 cm apart maintaining plant to plant distance of 10 cm at four sowing time *viz.* November 15 (S_1), November 22 (S_2), November 29 (S_3) and December 04 (S_4). Cultural practices *viz.*, thinning, irrigation, weeding etc. were done following Hand book of agricultural technology (Chowdhury and Hassan 2013).

Data on plant height, number of tillers, number of leaves and total dry matter per plant were recorded at an interval of 15 days from the age of 30 days up to harvest. Yield attributes and yield per plants were calculated after harvest at the age of 108 days. Twelve plants (3 plants from each replication) from each treatment were taken to record data on different growth and yield parameters. Data were analyzed statistically and treatment means were compared by LSD test at 5% level of significance (Steel *et al.* 1997).

Results and Discussion

Results presented in Table 1 showed that varietal effect had significant responses on plant height. At the early stage of growth (30 - 45 days), the maximum plant height was recorded from BARI Gom-28 (V_6) but, after the age of 45 days BARI Gom-24 (V_2) showed maximum height up to harvest. In case of sowing time, seeds sown on November 29 (S_3) produced tallest plants all over the growth period but, varied significantly up to the age of 60 days only. Results also showed that plant height responded significantly by combined treatments of variety and sowing time. BARI Gom-24 sown on November 29 (V_2S_3) resulted maximum height from the ages of 60 days up to harvest where, it was significantly different from most of the treatments. The height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors (Shahzad *et al*. 2007). Baloch *et al.* (2010) reported that plant height of wheat differed significantly by planting time.

The economic yield of most of the cereals is determined by the number of tillers. Results revealed that BARI Gom-27 (V_5) produced the highest number of tillers per plant all over the growth ages except at harvest (Table 2). Results also revealed that seeds sown on November 15 (S_1) produced the highest number of tillers per plant than rest of the sowing time throughout the growth periods and were significantly higher at the ages of 45 and 60 days and at harvest.

Table 1. Effect of sowing time on plant height of six varieties of wheat at different ages.

Treatments	30 days	45 days	60 days	75 days	90 days	At harvest
Variety (V)						
V_1	32.07 cd	43.22 bc	71.52 b	88.02 ab	89.68 a	90.04 a
V_2	33.69 b-d	46.79 ab	79.28 a	91.44 a	92.33 a	92.63 a
V_3	34.22 bc	45.13 ab	73.09 b	89.80 ab	91.42 a	91.68 a
V_4	35.22 ab	48.39 a	72.80 b	87.45 b	88.67 ab	89.08 ab
V_5	31.60 d	39.51 c	66.89 c	88.24 ab	90.33 a	90.70 a
V_6	36.26 a	48.51 a	72.16 b	83.53 c	84.43 b	84.97 b
Sowing time (S)						
V_1	33.13 bc	45.48 ab	72.18 b	86.62 a	87.80 a	88.08 a
V_2	35.29 ab	44.56 ab	68.58 b	87.44 a	89.95 a	90.23 a
V_3	35.53 a	48.80 a	76.96 a	90.36 a	91.27 a	91.70 a
V_4	31.42 c	42.18 b	72.77 ab	87.89 a	88.87 a	89.40 a
(V × S)						
V_1S_1	31.71 h-j	43.01 f-i	68.29 jk	83.25 ij	86.24 gh	86.80 g-i
V_2S_1	30.63 ij	44.36 e-i	75.99 b-e	87.35 d-h	88.34 d-h	88.61 e-i
V_3S_1	32.50 g-i	45.80 c-g	71.43 e-k	87.99 c-g	88.65 c-h	88.73 d-i
V_4S_1	34.25 d-g	49.61 a-c	73.49 c-g	86.24 e-i	86.70 f-h	87.13 g-i
V_5S_1	32.76 f-i	41.90 g-i	69.60 g-k	89.66 b-e	90.73 a-g	90.83 a-g
V_6S_1	36.93 a-c	48.19 a-e	74.26 c-f	85.24 f-i	86.18 gh	86.39 hi
V_1S_2	33.04 e-h	42.36 g-i	68.44 i-k	87.73 d-g	89.54 b-g	89.54 c-h
V_2S_2	36.14 a-d	47.80 b-f	76.33 b-d	92.71 ab	92.89 a-d	93.06 a-d
V_3S_2	35.24 b-e	44.49 d-i	70.53 f-k	89.70 b-e	93.81 ab	94.06 ab
V_4S_2	36.99 a-c	47.40 b-f	67.46 k	84.56 g-i	87.44 f-h	87.75 f-i
V_5S_2	32.73 f-i	37. 20 j-k	59.93 l	86.19 e-i	91.89 a-e	92.33 a-e
V_6S_2	37.61 a	48.11 a-f	68.83 h-k	83.74 h-j	84.14 h-i	84.63 ij
V_1S_3	33.80 e-h	47.03 b-f	76.34 b-d	90.16 b-d	91.00 a-f	91.60 a-f
V_2S_3	34.93 c-f	50.88 ab	84.63 a	94.00 a	94.84 a	94.91 a
V_3S_3	36.64 a-c	48.74 a-d	77.14 b-d	92.90 ab	93.64 ab	93.93 ab
V_4S_3	37.43 ab	51.32 ab	77.44 bc	90.61 a-d	91.53 a-e	91.95 a-f
V_5S_3	32.98 f-h	42.68 g-i	70.58 f-k	89.44 b-e	90.18 b-g	90.58 a-h
V_6S_3	37.44 ab	52.19 a	75.64 b-e	85.08 f-i	86.44 f-h	87.10 g-i
V_1S_4	29.74 jk	40.48 i-k	73.01 c-i	90.93 a-d	91.96 a-e	92.23 a-e
V_2S_4	33.06 e-h	44.13 e-i	80.20 a	91.71 a-c	93.24 a-c	93.81 a-c
V_3S_4	32.49 g-i	41.48 h-j	73.26 c-h	88.60 c-f	89.56 b-g	90.03 b-h
V_4S_4	32.20 g-i	45.21 d-h	72.80 d-j	88.39 c-f	89.00 c-g	89.49 c-h
V_5S_4	27.94 k	36.25 k	67.45 k	87.66 d-g	88.51 d-h	89.08 d-h
V_6S_4	33.08 e-h	45.55 c-h	69.91 f-k	80.08 j	80.95 i	81.78 j
CV (%)	9.82	12.68	9.09	5.56	6.06	5.78
LSD (0.05)	2.25	4.29	4.59	3.74	4.59	4.37

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5% level.

However, in case of combined effect, seeds of BARI Gom-25 sown on November 15 (V_3S_1) resulted the highest number of tillers per plant at all ages of growth except at 30 and 60 days where, V_5S_1 treatment produced maximum tillers per plant.

Table 2. Effects of sowing time on number of tillers per plant of six varieties of wheat at different ages.

Treatments	30 days	45 days	60 days	75 days	90 days	At harvest
Variety (V)						
V_1	2.72 b	6.56 ab	9.94 ab	10.59 ab	9.75 a	7.13 a
V_2	2.16 c	5.77 b	9.34 b	9.88 ab	8.94 a	5.47 c
V_3	2.31 bc	6.16 ab	8.75 b	9.53 b	9.00 a	6.38 b
V_4	2.66 b	6.17 ab	9.84 ab	10.88 ab	9.69 a	6.25 b
V_5	3.31 a	6.97 a	11.09 a	11.41 a	9.84 a	6.31 b
V_6	2.56 bc	6.02 ab	9.69 b	10.47 ab	9.66 a	6.75 ab
Sowing time (S)						
V_1	3.10 a	7.88 a	11.25 a	11.90 a	10.44 a	7.83 a
V_2	2.19 b	5.91 b	9.31 b	10.29 ab	9.13 a	6.96 b
V_3	3.10 a	6.73 b	9.58 b	10.13 b	9.40 a	5.94 c
V_4	2.08 b	4.58 c	8.96 b	9.52 b	8.96 a	4.79 d
(V × S)						
V_1S_1	2.50 g-i	7.06 c-e	10.13 d-f	11.13 ab	10.38 ab	8.25 a
V_2S_1	2.38 g-i	5.94 f-h	9.00 f-i	9.75 b-g	9.75 b-d	6.88 c-e
V_3S_1	3.50 c	9.25 a	12.25 ab	12.50 a	12.13 a	8.38 a
V_4S_1	3.25 cd	8.38 ab	11.88 bc	11.38 ab	10.63 ab	7.75 ab
V_5S_1	4.00 b	9.00 a	13.50 a	11.00 a-c	9.88 bc	8.25 a
V_6S_1	3.00 d-f	7.63 bc	10.75c-e	10.13 b-f	9.88 bc	7.50 bc
V_1S_2	2.75 e-g	6.31 fg	10.25 d-f	10.13 b-f	9.25 b-f	7.88 ab
V_2S_2	2.13 i-k	7.06 c-e	11.00 b-d	9.88 b-f	9.13 b-f	6.25 ef
V_3S_2	1.63 l	5.44 g-i	8.25 h-j	8.63 f-j	8.88 b-f	7.38 bc
V_4S_2	2.13 i-k	5.69 f-h	7.88 i-k	8.88 f-i	8.13 c-f	6.38 d-f
V_5S_2	2.13 i-k	5.06 h-j	7.88 i-k	9.25 d-h	9.13 b-f	6.88 c-e
V_6S_2	2.38 g-i	5.88 f-h	9.50 e-h	10.75 b-d	10.25 ab	7.00 cd
V_1S_3	3.13 c-d	7.44 b-d	10.38 de	10.00 b-f	10.13 a-c	6.88 c-e
V_2S_3	2.25 h-j	6.00 f-h	7.75 i-k	7.63 h-j	7.63 ef	4.38 jk
V_3S_3	2.38 g-i	5.56 f-h	6.88 k	7.63 h-j	7.25 f	5.00 h-j
V_4S_3	3.13 c-e	6.38 d-g	11.00 bd	9.00 e-i	10.38 ab	5.50 gh
V_5S_3	4.50 a	8.38 ab	11.13 b-d	9.38 c-g	10.63 ab	6.00 fg
V_6S_3	3.25 cd	6.63 c-f	10.38 de	10.63	10.38 ab	7.88 ab
V_1S_4	2.50 g-i	5.44 g-i	9.00 f-i	8.88 f-i	9.25 b-f	5.50 gh
V_2S_4	1.88 j-l	4.06 j	9.63 e-g	7.38 ij	9.25 b-f	4.38 jk
V_3S_4	1.75 kl	4.38 ij	7.63 jk	7.13 j	7.75 d-f	4.75 i-k
V_4S_4	2.13 i-k	4.25 j	8.63 g-j	9.38 c-g	9.63 b-e	5.38 g-i
V_5S_4	2.63 f-h	5.44 g-i	10.25 d-f	7.38 ij	9.75 b-d	4.13 k
V_6S_4	1.63 l	3.94 j	8.63 g-j	8.13 g-j	8.13 c-f	4.63 jk
CV (%)	13.88	9.44	10.76	10.31	13.99	13.87
LSD (0.05)	0.43	1.14	1.35	1.67	2.08	0.71

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5% level.

Results obtained from the present study corroborate with the findings of Jahan and Adam (2015) on BARI Gom-25. Ansary *et al.* (1989) also reported that delay sowing caused reduction in the number of tillers in wheat. However, Baloch *et al.* (2010) obtained non-significant effect on the number of tillers per unit area with sowing time.

Table 3. Effects of sowing time on number of leaves per plant of six varieties of wheat at different ages.

Treatments	30 days	45 days	60 days	75 days	90 days	At harvest
Variety (V)						
V_1	12.25 ab	24.36 a	55.04 a	42.25 a	28.47 a	17.78 a
V_2	11.16 c	22.48 a	44.97 c	40.66 a	26.03 a	13.59 c
V_3	11.81 a-c	22.81 a	45.38 c	40.19 a	27.16 a	15.59 bc
V_4	12.50 ab	22.88 a	47.50 bc	43.03 a	27.16 a	15.53 bc
V_5	12.81 a	24.59 a	51.16 ab	43.72 a	26.16 a	15.38 bc
V_6	11.72 bc	22.05 a	44.31 c	39.50 a	27.78 a	16.81 ab
Sowing time (S)						
V_1	13.81 a	27.97 a	55.04 a	50.56 a	33.60 a	20.06 a
V_2	11.04 b	20.60 b	45.75 b	40.19 b	27.25 b	16.38 b
V_3	13.25 a	26.44 a	47.40 b	39.71 b	25.69 b	14.27 c
V_4	10.06 b	17.77 b	39.08 c	35.77 b	21.96 b	12.42 c
(V × S)						
V_1S_1	11.50 e-g	26.19 b-d	51.00 d-f	43.75 a-c	35.75 ab	22.63 a
V_2S_1	10.63 gh	23.31 d-f	47.00 f-h	40.13 b-d	30.88 b-d	16.75 e-g
V_3S_1	16.13 a	31.44 a	60.00 b	48.13 a	38.50 a	23.13 a
V_4S_1	14.88 b	29.31 a-c	57.00 bc	46.69 ab	34.13 a-c	19.25 b-d
V_5S_1	16.25 a	31.00 a	64.63 a	46.50 ab	31.75 b-d	20.38 b
V_6S_1	13.50 c	26.56 b-d	50.63 d-f	39.75 b-d	30.63 b-e	18.25 c-e
V_1S_2	13.38 cd	23.50 de	49.75 ef	35.50 d-h	28.00 d-g	18.50 b-e
V_2S_2	13.00 cd	24.06 d	55.00 cd	39.75 b-d	29.38 c-f	15.25 gh
V_3S_2	10.38 hi	19.44 f-h	43.00 h-j	32.38 b-d	26.13 d-i	14.88 gh
V_4S_2	10.75 ef	19.38 gh	41.38 i-k	34.38 d-h	24.63 e-j	15.50 gh
V_5S_2	7.88	17.38 gh	43.50 hi	36.13 d-g	26.88 d-h	16.75 e-g
V_6S_2	10.88 f-h	19.88 e-g	41.88 i-k	36.63 c-f	28.50 c-g	17.38 d-f
V_1S_3	12.38 de	28.88 a-c	49.75 ef	36.88 c-e	26.88 d-h	16.25 fg
V_2S_3	11.75 ef	24.94 d	41.50 i-k	32.50 e-h	23.75 f-j	11.13 j
V_3S_3	11.38 e-h	23.44 de	40.75 i-l	29.50 f-h	22.50 g-j	10.75 j
V_4S_3	14.00 bc	25.50 cd	52.25 de	36.50 d-g	24.00 f-j	13.50 hi
V_5S_3	16.38 a	29.94 ab	51.50 d-f	35.25 d-g	26.00 d-j	14.13 h
V_6S_3	13.63 c	25.94 cd	48.63 e-g	40.00 b-d	31.00 b-d	19.88 bc
V_1S_4	11.75 ef	18.88 gh	39.88 j-m	34.25 d-g	23.25 g-j	13.75 hi
V_2S_4	9.25 j	17.63 gh	36.38 lm	30.50 e-h	23.25 g-j	11.25 j
V_3S_4	9.38 ij	16.94 gh	37.75 k-m	28.75 h	20.13 ij	13.63 hi
V_4S_4	10.38 hi	17.31 gh	39.38 j-m	33.44 d-g	21.50 h-j	13.88 h
V_5S_4	10.75 f-h	20.06 e-g	45.00 g-i	30.38 e-h	25.88 d-j	10.25 j
V_6S_4	8.88 jk	15.81 h	36.13 m	29.38 gh	20.00 j	11.75 ij
CV (%)	10.81	15.87	16.01	14.02	7.92	15.72
LSD (0.05)	1.00	3.88	4.57	7.15	6.10	2.02

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5% level.

Results presented in Table 3 revealed that number of leaves per plant had similar trend as obtained in number of tillers per plant but with few exceptions. The maximum number of leaves per plant was recorded from November 15 sown wheat (S_1) throughout the growth stage although, statistically at par with November 29 sown wheat (S_3) at 30 and 45 days. The combined effect of V_3S_1 treatment also resulted the highest number of leaves per plant throughout life span except at 30 and 60 days. Results obtained from this investigation were found to be consistent with the findings of Jahan and Adam (2015) where, they recorded maximum number of leaves per plant from November 14 sown BARI Gom-25 in most of the growth ages.

Table 4 showed that BARI Gom-25 (V_3) produced the highest total dry matter (TDM) throughout the growth stages but with exception of 30 and 60 days whereas, in case of sowing time the maximum value was obtained from November 15 sown wheat (S_1) at all ages of growth. Similarly, maximum TDM was noted from November 15 sown BARI Gom-25 (V_3S_1) at all growth stages and found significantly different from rest of the combined treatments at 60, 75 and 90 days. The production of higher TDM per plant of BARI Gom-25 might be due to increased vegetative growth on optimum time of sowing.

Table 4. Effects of sowing time on total dry matter per plant of six varieties of wheat at different ages.

Treatments	30 days	45 days	60 days	75 days	90 days	At harvest
Variety (V)						
V_1	0.66 ab	1.87 b	3.86 a	16.56 b	19.54 b	29.42 a
V_2	0.70 ab	2.16 a	4.09 a	18.50 a	21.55 a	31.50 a
V_3	0.71 ab	2.21 a	4.12 a	18.62 a	21.90 a	31.82 a
V_4	0.76 a	1.96 ab	4.30 a	17.67 ab	20.18 b	29.96 a
V_5	0.63 b	2.07 ab	4.35 a	15.14 c	18.26 c	28.04 a
V_6	0.64 b	2.05 ab	3.99 a	15.10 c	17.99 c	28.05 a
Sowing time (S)						
V_1	0.77 a	2.61 a	4.65 a	18.43 a	21.12 a	34.29 a
V_2	0.66 bc	1.48 b	3.07 b	16.50 bc	20.55 a	29.01 b
V_3	0.74 ab	2.55 a	4.43 a	17.37 ab	20.14 a	28.85 b
V_4	0.57 c	1.57 b	4.33 a	15.42 c	17.79 b	27.04 b
(V × S)						
V_1S_1	0.76 a-c	2.06 e	3.96 de	15.79 fg	18.73 k-n	33.03 b-d
V_2S_1	0.78 ab	2.84 ab	4.78 bc	19.83 b	23.43 b	35.83 ab
V_3S_1	0.81 a	3.01 a	5.70 a	23.07 a	25.66 a	39.01 a
V_4S_1	0.80 a	2.36 d	4.21 c-e	18.67 bc	19.97 e-j	34.20 bc
V_5S_1	0.69 b-d	2.84 ab	4.84 b	18.47 c	20.08 e-i	32.97 b-e
V_6S_1	0.78 ab	2.54 cd	4.40 b-e	14.77 gh	18.86 j-n	30.70 c-g
V_1S_2	0.67 cd	1.11 h	2.57 f	14.13 hi	19.18 i-n	29.12 e-i
V_2S_2	0.77 a-c	1.63 fg	2.86 f	17.69 c-e	21.04 e-e	32.17 b-f
V_3S_2	0.79 ab	1.76 f	2.28 f	15.62 fg	21.82 c	30.75 c-g
V_4S_2	0.78 ab	1.57 f-h	4.20 de	17.75 c-e	21.07 c-e	29.35 d-i
V_5S_2	0.54 fg	1.35 h	3.83 e	17.09 de	20.41 d-h	26.68 h-j
V_6S_2	0.41 h	1.46 gh	2.69 f	16.72 ef	19.80 f-k	25.98 ij
V_1S_3	0.65 de	2.52 cd	4.47 b-d	18.35 cd	20.94 c-f	27.69 g-i
V_2S_3	0.77 a-c	2.44 cd	4.46 b-d	18.08 cd	21.34 cd	29.91 d-h
V_3S_3	0.78 ab	2.59 b-d	4.40 b-e	18.26 cd	20.60 d-g	29.15 e-i
V_4S_3	0.80 a	2.52 cd	4.41 b-e	18.52 c	21.49 cd	28.29 g-i
V_5S_3	0.72 a-d	2.64 bc	4.37 b-e	12.93 ij	18.14 n	25.78 ij
V_6S_3	0.74 a-d	2.59 b-d	4.46 b-d	18.10 cd	18.36 ln	32.25 b-e
V_1S_4	0.55 e-g	1.77 f	4.44 b-d	17.97 c-e	19.32 h-m	27.83 g-i
V_2S_4	0.49 gh	1.75 f	4.27 b-e	18.40 c	20.40 d-h	28.07 g-i
V_3S_4	0.48 gh	1.46 gh	4.11 de	17.54 c-e	19.50 g-l	28.35 f-i
V_4S_4	0.67 cd	1.38 gh	4.37 b-e	15.74 fg	18.18 mn	28.01 g-i
V_5S_4	0.56 e-g	1.45 gh	4.36 b-e	12.07 jk	14.39 o	26.74 h-j
V_6S_4	0.64 d-f	1.63 fg	4.41 b-e	10.81 k	14.95 o	23.27 j
CV (%)	11.24	9.61	11.89	16.43	12.44	6.89
LSD (0.05)	0.10	0.25	0.59	1.27	1.16	3.86

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5% level.

Data obtained on yield attributes and yield are presented in Table 5. In case of varietal effect, the maximum number of grains per plant, dry weight of spike, 1000-grain weight, yield per plant, yield per hectare and harvest index were recorded from BARI Gom-25 (V_3).

Table 5. Effects of sowing time on yield attributes and yield of six varieties of wheat.

Treat-ments	No. of effective tillers/plant	No. of non-effective tillers/plant	No. of grains/ spike	No. of grains/ plant	Length of spike (cm)	Dry weight of spikes (g)	1000-grain weight (g)	Yield/ plant (g)	Yield/ ha (t)	HI (%)
Variety (V)										
V_1	6.59 a	0.53 a	24.06 c	158.73 a	8.81 c	17.10 cd	45.08 b	7.44 c	3.72 c	25.39 ab
V_2	5.25 c	0.22 a	32.08 a	165.62 a	10.37 a	19.12 ab	48.91 a	8.38 ab	4.19 ab	26.48 a
V_3	6.19 ab	0.19 a	28.28 b	172.79 a	9.49 b	20.70 a	49.04 a	8.75 a	4.38 a	27.48 a
V_4	5.88 b	0.38 a	28.53 b	168.12 a	8.95 c	18.41 bc	42.18 d	7.39 c	3.69 c	24.76 ab
V_5	6.09 ab	0.22 a	28.11 b	168.81 a	9.01 bc	16.37 d	35.99 e	6.25 d	3.12 d	22.42 b
V_6	6.38 ab	0.38 a	26.06 bc	167.29 a	7.87 d	16.87 d	43.50 c	7.61 bc	3.81 bc	27.08 a
Sowing time (S)										
V_1	7.46 a	0.38 a	28.80 a	214.73 a	9.25 a	20.09 a	45.65 a	9.81 a	4.90 a	28.81 a
V_2	6.54 b	0.42 a	24.97 b	162.25 b	8.78 a	17.28 b	44.65 b	7.45 b	3.73 b	25.77 ab
V_3	5.73 c	0.21 a	28.29 a	159.07 b	9.16 a	17.62 b	43.71 c	7.25 b	3.63 b	25.42 ab
V_4	4.52 d	0.27 a	29.35 a	131.51 c	9.15 a	17.39 b	42.46 d	6.03 c	3.01 c	22.40 b
(V × S)										
V_1S_1	7.63 a-c	0.63 ab	27.09 d-h	206.36 bc	9.02 e-i	19.01 b-e	46.28 f	9.67 b-d	4.83 b-d	29.41 a-c
V_2S_1	6.75 e-f	0.13 c	29.94 bc	202.21 bc	10.36 ab	20.48 b	50.19 b	10.23 b	5.12 b	28.69 a-d
V_3S_1	8.13 a	0.25 bc	29.20 b-e	236.79 a	10.00 bc	24.17 a	50.64 a	11.99 a	6.00 a	30.92 a
V_4S_1	7.38 cd	0.38 bc	30.06 b	221.50 ab	8.87 f-i	20.38 b	43.57 k	9.73 b-d	4.87 b-d	28.78 a-d
V_5S_1	8.00 ab	0.25 bc	28.63 b-f	229.27 a	9.12 d-g	18.51 c-g	37.64 q	8.49 e	4.24 e	25.93 c-h
V_6S_1	6.88 d-f	0.63 ab	27.90 b-f	192.26 cd	8.14 jk	18.02 d-h	45.60 g	8.75 e	4.37 e	29.14 a-c
V_1S_2	6.88 d-f	1.00 a	21.34 k	146.25 g-k	8.53 ij	15.92 i-k	45.36 h	6.85 f-h	3.43 f-h	24.07 e-i
V_2S_2	6.00 gh	0.25 bc	29.45 b-d	176.14 ef	10.64 a	18.28 d-g	49.43 c	8.91 de	4.46 de	27.71 a-e
V_3S_2	7.25 c-e	0.13 c	24.96 g-i	180.35 de	8.96 e-i	20.01 bc	49.31 c	9.13 c-e	4.57 c-e	29.91 ab
V_4S_2	5.88 h	0.50 bc	27.39 c-g	160.79 fg	8.97 e-i	18.60 c-f	42.69 l	7.07 fg	3.53 f	24.11 e-i
V_5S_2	6.50 fg	0.38 bc	24.50 h-j	159.38 f-h	8.65 g-j	15.01 k	36.54 r	5.90 i	2.95 i	22.40 g-i
V_6S_2	6.75 e-f	0.25 bc	22.20 jk	150.62 g-j	6.92 l	15.82 i-k	44.54 j	6.85 f-h	3.43 f-h	26.42 b-f
V_1S_3	6.63 f	0.25 bc	22.84 i-k	151.39 g-i	8.52 ij	16.36 h-k	45.08 i	7.09 f	3.55 f	26.17 b-g
V_2S_3	4.13 lm	0.25 bc	35.29 a	145.38 g-k	10.26 ab	19.18 b-d	48.75 d	7.36 f	3.68 f	24.54 e-i
V_3S_3	4.88 i-k	0.13 c	29.27 b-e	140.87 g-k	9.43 de	19.63 b-d	48.63 d	7.13 f	3.57 f	24.93 d-i
V_4S_3	5.25 i	0.25 bc	26.75 e-h	140.38 h-k	8.97 e-i	17.33 e-i	41.82 n	6.17 g-i	3.08 g-i	22.25 hi
V_5S_3	6.00 gh	0.00 c	26.50 f-h	159.13 f-h	9.19 d-f	15.05 k	35.53 s	5.89 i	2.94 i	23.42 f-i
V_6S_3	7.50 bc	0.38 bc	29.07 b-f	217.29 ab	8.60 h-j	18.18 d-g	42.45 m	9.88 bc	4.94 bc	31.23 a
V_1S_4	5.25 i	0.25 bc	24.97 g-i	130.91 jk	9.16 d-g	17.13 f-j	43.60 k	6.13 hi	3.07 hi	21.93 i
V_2S_4	4.13 lm	0.25 bc	33.66 a	138.77 i-k	10.23 ab	18.53 c-g	47.26 e	7.02 f-h	3.51 fg	24.99 d-i
V_3S_4	4.50 j-l	0.25 bc	29.69 bc	133.15 i-k	9.59 cd	18.98 b-e	47.60 d	6.74 f-i	3.37 e	24.15 e-i
V_4S_4	5.00 ij	0.38 bc	29.94 bc	149.81 g-j	8.99 e-i	17.34 e-i	40.62 p	6.58 f-i	3.29 f-i	23.89 e-i
V_5S_4	3.88 m	0.25 bc	32.79 a	127.45 kl	9.10 d-h	16.89 g-j	34.27 t	4.72 j	2.36 j	17.93 j
V_6S_4	4.38 k-m	0.25 bc	25.06 g-i	109.00 l	7.82 k	15.46 jk	41.39 o	4.96 j	2.48 j	21.53 ij
CV (%)	13.18	16.67	15.05	14.06	10.61	14.29	10.47	6.02	6.01	9.31
LSD (0.05)	0.59	0.47	2.59	20.23	0.51	1.69	0.20	0.90	0.43	3.90

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5% level.

In case of combined treatments, findings revealed that the maximum number of effective tillers per plant was recorded from BARI Gom-25 when sown on November 15 (V_3S_1) which was statistically identical to V_1S_1 and V_5S_1 treatments (Table 5). This finding is contradictory to the results of Shahzad *et al.* (2007) who reported that wheat sown on December produced significantly more number of productive tillers than the crop sown on November. The highest number of grains (236.79) per plant was also recorded from V_3S_1 treatment which was significantly different from majority of the treatments. However, the maximum number of grains per spike was obtained from V_2S_3 treatment. Jahan and Adam (2015) also reported non-significantly higher number of grains per plant in BARI Gom-25 sown on November 24. Besides results showed that the maximum length of spike was obtained from BARI Gom-24 when sown on November 22 (V_2S_2) followed by November 15 (V_2S_1). Research report revealed that earlier planting resulted in better spike development due to longer growing period (Waraich *et al.*1981).

Results of this study also showed that significantly maximum dry weight of spike, 1000-grain weight, yield per plant and yield per hectare were recorded from BARI Gom-25 when sown on November 15. Findings of Jahan and Adam (2015) revealed that November 14 sown wheat produced maximum 1000-grain weight and there was a gradual decreasing trend with delayed sowing. The results are also in agreement with the previous reports (Subhan *et al*. 2004, Abdullah *et al*. 2007, Shahzad *et al*. 2007).

Table 5 shows that sowing time had significant effect on yield per plant and yield per hectare and findings of this experiment indicated that November 15 was the most suitable sowing time for most of the varieties. Results also indicated that yield of wheat varieties decreased gradually with delayed sowing although, BARI Gom-28 produced higher yield on November 29 than other sowing time. Shah and Akmal (2002) and Ali *et al.* (2010) reported that different varieties responded differently on different sowing dates. Findings of present investigation also showed that BARI Gom-25 (V_3) produced maximum yield (11.99 g) on optimum time of sowing followed by BARI Gom-24 (10.23 g). Yield of BARI Gom-25 reduced by 23.85, 40.53 and 43.79% at 7, 14 and 21 days delay in sowing, respectively. Jahan and Adam (2015) obtained statistically similar yield from November 14 and November 24 sown BARI Gom-25 but decreased significantly beyond the time of November 24. Decrease in grain yield of wheat due to delay sowing from November 20 onward was also reported by Singh and Uttam (1999). Ansary *et al.* (1989) and Shahzad *et al*. (2007) also obtained lower yield with delay sown wheat. Regardless of varieties or cultivars, better yields were obtained when wheat was sown after November 15 and before November 30 (Akhtar *et al.* 2006). Baloch *et al.* (2010) recorded maximum grain yield when sown in November while minimum in December. Among the six varieties, BARI Gom-25 produced maximum harvest index (27.48). Results also revealed that seeds sown on November 15 resulted the highest HI (28.81). In case of combined effect, although HI was recorded maximum due to BARI Gom-28 sown in November 29 (V_6S_3) followed by BARI Gom-25 sown in November 15 (V_3S_1), but both of them were not found statistically different.

Out of six varieties of wheat, BARI Gom-25 was the best performed variety and among the four sowing time, November 15 was optimum for most of the varieties.

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(Manuscript received on 19 February, 2018; revised on 25 May, 2018)