IMPROVEMENT OF GRAIN AND NUTRITIONAL QUALITIES OF RICE VARIETIES THROUGH BREEDING

Ph.D. DISSERTATION

By

NILUFA FERDOUS

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A DISSERTATION SUBMITTED TO THE UNIVERSITY OF DHAKA IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN BIOCHEMISTRY AND MOLECULAR BIOLOGY

DEPARTMENT OF BIOCHEMISTRYAND MOLECULAR BIOLOGY, FACULTY OF BIOLOGICAL SCIENCES, UNIVERSITY OF DHAKA, DHAKA-1000, BANGLADESH

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DECLARATION

I hereby declare that this thesis entitled **"Improvement of grain and nutritional qualities of rice varieties through breeding"**,nowsubmitted for the degree of 'Doctor of Philosophy in Biochemistry and Molecular Biology', has been composed by myself and the results presented herein are based on my own research work. I further declare that this work has not been submitted for the award of any other degree or diploma.

November 2016 **(NilufaFerdous)**

CERTIFICATE

This is to certify that NilufaFerdous has conducted her thesis work entitled**“Improvement of grain and nutritional qualities of rice varieties through breeding”**under my supervision for fulfillment of the degree ‘Doctor of Philosophy in Biochemistry and Molecular Biology’ from the University of Dhaka. Furthermore, Dr.Sunil Kumar Biswas, Professor, International University of Business, Agriculture and Technology (IUBAT), Bangladesh has worked on Nilufa’s research activities as a co-supervisor. This is further to certify that the research work presented herein is original.

Supervisor

(Prof. Md. Zakir Hossain Howlader, Ph.D.)
Department of Biochemistry and Molecular Biology
University of Dhaka, Bangladesh

Dedicated to my husband

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NilufaFerdous

ABSTRACT

The study was conducted to identify promising rice cultivars for developing high yielding variety with superior grain and nutritional qualities. It included 109 local germplasm cultivars and 20 high yielding varieties. Out of 129 rice cultivars, there were 36 long, 62 medium and 31 short grain cultivars.

The study provided information on the agronomic characters of long, medium and short grain cultivars. Seven long grain cultivars (Boradudhkalam, Dudhkalam, Gohatibinni, Harilaxmi, Kanaibansi, Patnai-231 and Shata) varied in rough rice yield (4.0-5.2 t/ha), plant height(110-180cm) and growth duration (120-160 days) as well as those five medium grain rough rice cultivars (Ganjia, Gojalgoria, Jhoshuoa, Kajalsail andTilokajal) varied in rough rice yield (4.0-4.5t/ha), plant height (137-161cm) and growth duration (142-155 days).Eleven short grain cultivars (Betudhan,Binniphul, Chinisagor, Dudsail, Gurdoi, Khasa, Lalsaru, Nariabochi, Pajam, Sorukamina and Tulsimala) varied inrough rice yield (3.0-3.9 t/ha), plant height (140-193cm) and growth duration (116-155days).

The color of rough rice of these cultivars, dehulledbefore milling, was mostly brown. Only 46 cultivars had red pericarp. The dehulled rice was milled to remove 10% bran-polish. Milling yield and head rice recovery of long grain cultivars varied from 63% to 71% and 41% to 96% respectively. Seven long grain cultivars (Boradudhkalam,Dudhkalam, Gohatibinni, Harilaxmi, Kanaibansi, Patnai-231 and Shata) as well as seven medium grain cultivars (Ganjia, Gojalgoria, Jhoshuoa, Kajalsail,Kanaklota, Maloti and Tilokkajal) had acceptable (> 67%) milling yield.

Among the 129 cultivars, 24 had aroma, 16 had long slender and 85 had translucent grains. The cultivars having long slender grain with translucent kernel are preferred all over. Cultivars of Karailadhan, Pakhisail and Neda had long slender and translucent grains. The milled rice length of these cultivars were more than 7.0 mm.

Amylose content in rice cultivar is an important factor influencing cooking and eating qualities. Long slender grains with intermediate to high amylose (20-29%), giving soft cooked rice, are suitable for export market and medium grains with high amylose, giving fluffy cooked rice, are preferred by hardworking people. Cultivars with high elongation ratio (>1.9) are preferred all over. Results showed that cultivars varied in amylose content from 5% to 29% and elongation ratio from 1.5 to 2.2. None of the long slender grain had

more than 2.0 elongation ratio in this study. Medium grain cultivars (Ganjia,Kanaklota, Maloti and Tilokkajal) had more than 1.9 elongation ratio.

Analysis of mineral contents (phosphorous, calcium, magnesium, nitrogen, potassium, sodium, iron and zinc) of the total cultivars showed that phosphorous, sodium and iron content were higher in the tested local cultivars than the HYVs irrespective of grain size and shape. Zinc content was significant and positively correlated with iron content.

Protein content, protein digestibility, fractionation of protein and amino acid composition of rice cultivars may provide substantial information on protein nutritional value. Protein content of total cultivars varied from 6.5% to 10.7%. Magoibalam, Harilaxmi and Tilokkajalcultivars had 10.7%, 9.2% and 8.8% protein respectively. Amino acid composition of protein from promising cultivars showed that the cultivars varied from 3.34-4.29g/100g lysine, 3.34-3.97g/100g threonine, 2.09-2.23 g/100g methionine and 1.36-2.40g/100g cysteine. The invitro protein digestibility of Magoibalam, Motichak, Neda, Molladigha and Boylam varied from 67% to 78%. The highest invitro protein digestibility was observed in Magoibalam.

The in vitro starch digestibility of cultivars varied from 62.3% to 83.8%at 120 minutes digestion. Low amylose (6.0-18)% of long grain cultivars of Athabinni, Kalabinni-1 and Kanaibansi as well asmedium grain cultivar of Ledabinni had more than 80% starch digestibility.High amylose (>25%) long grain cultivars of Boradudkalam, Depa, Dudkalam, Karailadhan, Molladiga and Patnai-231 had starch digestibility between 62.3% and 66.6%. On the other hand, high amylose (>25.0%) medium grain cultivars of Magoibalam and Motichak had 70.6% and 75.5% starch digestibility respectively.

Genetic diversity of *Waxy* gene in selected rice cultivars was evaluated by using microsatellite marker and cleaved amplified polymorphic sequence marker. Results showed that Microsatellite marker (RM190) and cleaved amplified polymorphic sequence marker (RM190F-GBSSW2R/*AccI*) had efficacy to differentiate amylose status on the basis of allelic variation and single nucleotide (G/T) polymorphism of the *Waxy* gene. The hybrid vigor of Motichak × BRRI dhan28 (F_1 seed) had 103 cm plant height, 9.1% protein and 26.7% amylose compared with parent. Three crosses were made as successful F_1 hybridization. Evaluation of F_1 hybridization and its confirmation on the basis of morphological and nutritional performances was found promising.

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LIST OF ABBREVIATIONS

%	Percentage
µg	Microgram
µL	Microliter
AAC	Amino Acid Composition
AAC	Apparent Amylose Content
AccI	Restriction Digestion Enzyme
AOAC	Association of Official Analytical Chemists
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
bp	Base pair
BRRI	Bangladesh Rice Research Institute
C	Celsius
Ca	Calcium
CAPS	Cleaved Amplified Polymorphic Sequence
CTAB	Cetyl Trimethyl Ammonium Bromide
cm	Centimeter
CV	Coefficient of Variation
ddH_2O	Distilled deionized water
DNA	Deoxyribonucleic acid
EDTA	Ethylene diamine tetra acetic acid
FAO	Food and Agriculture Organization
Fe	Iron
g or gm	Gram
GRS	Genetic Resource and Seed
h or hr	Hour
HYVs	High Yielding Varieties
IRRI	International Rice Research Institute
K	Potassium
kb	Kilobase
Kg	Kilogram
L	Length

L/B	Length by Breadth ratio
LB	Long Bold
LS	Long Slender
LSD	Least Significant Difference
MB	Medium Bold
mg	Milligram
Mg	Magnesium
ml	Milliliter
mm	Millimeter
MR	Medium Round
MS	Medium Slender
N	Nitrogen, Normality
ng	Nano gram
nm	Nanometer
Na	Sodium
NaCl	Sodium Chloride
NaOH	Sodium hydroxide
P	Phosphorous
PAGE	Poly Acrylamide Gel Electrophoresis
PCR	Polymerase Chain Reaction
ppm	Parts per million
RNA	Ribonucleic acid
rpm	Rotation per minute
SB	Short Bold
SNP	Single Nucleotide Polymorphism
SR	Short Round
SSR	Simple Sequence Repeat
T. Aman	Transplanted Aman season
t/ha	Ton per hector
Tr	Translucent
UV	Ultraviolet
V/V	Volume by Volume
Wb5	White belly
Wc1	White center
W/V	Weight by Volume

Zn	Zinc

SUMMARY

Children require sufficient protein daily to meet their potential growth and development. Rice provides about 55% of protein intake in the average daily diet of our people. Rice is a starchy food and its amylose content influences eating and cooking qualities. Rice-based food security with improved nutritional quality is important for commercial value of rice grade for export market and local consumption of people taking more rice in a day. To identify superior quality rice germplasm in the field experiment, 109 local cultivars and 20 high yielding varieties (HYVs) were collected from the BRRI Gene Bank of Genetic Resource and Seed (GRS) Division, Gazipur. The field experiment was conducted in the farm of Bangladesh Rice Research Institute (BRRI), Gazipur in T. Aman season, 2009.The samples were analyzed mostly at BRRI laboratory and some at other laboratories outside BRRI.

Among the local rice cultivars, Dudhkalam gave the highest yield (5.2 t/ha) and Magoibalam, the lowest yield (0.9 t/ha). Boradudhkalam gave the highest thousand grain weight (38.1 g) but both Laxmikajol and Jirakatari-1 gave the lowest thousand grains weight (10.3 g).Both Najirsail and Topaboro gave the highest number of tiller/hill (17) but Molladigha, TK deep straw Tapl-773, Shata, Motichak and Murchmut gave the lowest number of tiller/hill (9). Topaboro had the highest number of panicle/hill (14) but Rahikhama had the lowest(6). Kanaibansi had the highest panicle length (31 cm) but Topaboro, the lowest (18 cm). Pakibiroin had the highest plant height of 205 cm but Topaboro had the lowest plant height of 86 cm. Joyna had the highest growth duration of 174 days but Gobcha had the lowest of 106 days and Shamrosh had the highest percent of filled grains (98%) but Dholagachha, the lowest (39%).

Results showed that yield of long grain rice cultivars ranged 1.1-5.2 t/ha, that of medium grain rice cultivars 0.9-5.6 t/ha and short grain cultivars 1.5-3.9 t/ha.The thousand grain weightof long grain rice cultivars ranged 18.1-38.1 g, that of medium grain rice cultivars12.1-31.7 g and short grain cultivars10.3-26.2 g.The number of tiller/hill ranged 9-15 in long grain cultivars and 9-17 in both medium and short grain rice cultivars. Thenumber of panicle/hill ranged 7-11in long, 7-13 in medium and 6-14 in short grain rice cultivars. The panicle length of long grain rice cultivars ranged 21.7-30.8 cm, that of medium grain rice cultivars20.8-29.3 cm and short grain cultivars18-29.2 cm. The plant height of long grain rice cultivars ranged106-179.6 cm, that of medium grain rice

cultivars100-205.2 cm and short grain cultivars 86.4-193.2 cm.The growth duration ranged 115-171 days, 106-174 days and 107-155 days as well as the percent of filled grains ranged 54-97%, 39-98% and 54-95% in long, medium and short grain rice cultivars respectively.

In all categories of tested rice cultivars, local cultivars had higher mean of thousand grain weight and plant height than the HYVs. Among the long grain rice cultivars, local cultivars had higher mean of number of tiller/hill, number of panicle/hill and growth duration than the HYVs. Among the medium and short grain rice cultivars, local ones had higher mean percent of filled grains than the HYVs. Among the short grain rice cultivars, local ones had higher meanpanicle length than the HYVs.

In long and medium grain rice cultivars, 31% and 26% yield of rice cultivars were classified as high yield (>3.9 t/ha). Similarly, 36% and 18% thousand grain weight of long and medium grain rice cultivars were classified as very high thousand grain weight (>27 g). But at the level of (15-19) g, long, medium and short grain rice cultivars had 3%, 13% and 13% low thousand grain weight respectively. In the case of intermediate tillering ability(10-19), all categories of cultivars were 92%, 98% and 97%.In long, medium and short grain rice cultivars, 25%, 21% and 19% panicle number/hill were classified as many panicle number/hill(>10). Long grain rice cultivars had 3% very long panicle length(>30 cm). At the level of (90-110) cm, both long and medium grain rice cultivars had 6% intermediate plant height as well asshort grain rice cultivars had only3% short plant height (<90 cm). For short duration (<121 days), long, medium and short grain rice cultivars had 11%, 6% and 19% respectively. In the case of high percent of filled grains (>90%), long, medium and short grain rice cultivars had 19%, 19.4% and 13% respectively.

In long grain rice cultivars thousand grain weight and panicle length were significant and positively correlated with yield; in medium grain rice cultivars number of panicle/hill, panicle length and percent of filled grains were significant and positively correlated with yield as well as in short grain rice cultivars thousand grain weight, number of tiller/hill, plant height, growth duration and percent of filled grain were positively correlated with yield. On the basis of clustering thousand grain weight, panicle length, number of panicle/hill, number of tiller/hill and percent of filled grains had very close relationship with yield but plant height and growth duration both had weak relationship with yield in the local rice cultivars.

Out of 129 rice cultivars, 36 had long, 62medium and 31 short grain. Among them, 67, 56 and 6 cultivars had difficult, intermediate and easy panicle threshability; 48, 66 and 15 cultivars had compact, intermediate and openpanicle type; 112 and 17 cultivars had awnless and awn; 54, 7, 29, 18,2, and 19 cultivarshad golden hull color, golden with different mixed hull color, straw hull color, black hull color, black with different mixed hull color andpurple hull color of whole paddy; 46 and 83cultivarshad red and brown pericarp color; 16, 20, 3, 53, 6, 19, and 12 cultivarshad long slender (LS), long bold (LB), medium slender (MS), medium bold (MB), medium round (MR), short bold (SB) and short round (SR) type size and shape; 85, 26, 8, and 10 cultivarshad translucent, white belly, white center and opaque grainas well as 1,21 and 107 cultivarshad excellent, very good and good appearance.

Among the rice cultivars of long, medium and short grain, paddy length varied from 5.8 mm to 12.1 mm; paddy breadth varied from 2.1 mm to 3.5 mm; paddy L/B ratio varied from 1.9 to 5.2; brown rice length varied from 4.0 mm to 8.3 mm; brown rice breadth varied from 1.8 mm to 3.0 mm; brown rice L/B ratio varied from 1.5 to 4.3; milled rice length varied from 3.7 mm to 7.4 mm; milled rice breadth varied from 1.6 mm to 2.9 mm and milled rice L/B ratio varied from 1.4 to 4.2. Prominent cultivars such as Khorma, Boradudhkalam, Shata,Patnai-231, Dudhkalam, Kalabinni-1, Neda, Pakhisail and Karailadhan had the highest range of milled rice length of (7.0-7.4) mm and paddy length of (10.4-12.1) mm. Khorma, Neda, Pakhisail and Karailadhan of these cultivars had the lower range of milled rice breadth of (1.8-1.9) mm and the highest range of L/B ratio of (3.9-4.2).

In the long grain rice cultivars, length, breath and L/B ratio of local paddy and local milled rice had higher than the HYVs. In the medium grain rice cultivars, breadth oflocal paddy andlocal brown rice as well as breadth and length of local milled rice had higher than the HYVs. In the short grain rice cultivars, length and breadth of local paddy, local brown rice and local milled rice had higher than the HYVs.Among the rice cultivars, paddy L/B ratio was highly significant and positively correlated with brown rice L/B ratio and milled rice (L/B) ratio. Milled rice length was significant and positively correlated with brown rice length and paddy length. Milled rice length was positively correlated with milled rice (L/B) ratio and milled rice breadth.

Among the local rice cultivars, Bolonga had the highest milling outturn (74%) but Chinisagor had the lowest milling outturn (59%); Dudsail and Chinigura had the highest head rice recovery (98%) but Motichak had the lowest head rice recovery (26%); Kharmao had the highest hull content (27%) but Bolonga, Kataribhog-2, Hathazi and Chunikanai had the lowest hull content (20%); Cylindrical Tapi-629 and Rangabinni had the highest alkali spreading value (7) but Kanaibansi had the lowest alkali spreading value (3.2); Jol, Molladigha, Kalisayta and Nurior had the highest cooking time (23 minutes) but Lalsoru, Khasha and Jirakatari-2 had the lowest cooking time (13 minutes); Chunikanai, Lalsaru and Surjyamukhisangla had the highest elongation ratio (2.3) but Jingasail-1, Gohatibinni, Lalsoru, Magoibalam, Ledabinni and Kataribhog-232 had the lowest elongation ratio (1.5) as well as Hashfol had the highest volume expansion ratio (4.3) but Athabinni, Gohatibinni, Kalabinni-1 and Rangabinni had the lowest volume expansion ratio (3.1). In these local rice cultivars 82 had intermediate but 47 had low gelatinization temperature as well as 24 had aroma but 105 had no aroma.

Furthermore, results showed that the ranges of milling outturn had (63-71)%, (59-74)% and (59-72)%; the ranges of head rice recovery had (41-96)%, (26-98)% and (75-98)%; the ranges of hull content had (21-27)%, (19-26)% and (20-26)%; the ranges of alkali spreading value had (3.2-7.0)%, (3.8-7.0)% and (3.7-6.4)%; the ranges of cooking time had (15-23) minutes, (13-23) minutes and (13-23) minutes; the ranges of elongation ratio had (1.5-2.0), (1.5-2.2) and (1.8-2.3) as well asthe ranges of volume expansion ratio had (3.1-4.0), (3.1-4.3) and (3.4-4.0)in long, medium and short grain rice cultivars respectively.

Among the rice cultivars, more than 70% milling outturn of long, medium and short grain were5.6%, 19.4% and 10%; more than 95% head rice recovery of long, medium and short grain were 6.3%, 17.7% and 48.4%;less than 20% hull contentof medium and short grain were 10% and 3.2%; at the range of (4-5) alkali spreading value of long, medium andshort grain were 19%, 35% and 48%; intermediate gelatinization temperature of long, medium and shortgrain were 56%, 63% and 74%;less than 15 minutes cooking time of long, medium and shortgrainwere 6%, 13% and 58%; more than 2 elongation ratio of medium and short grain were 18% and48.4%; more than 3.9 volume expansion ratioof long, medium and short grainwere 8.3%, 24% and 16%as well as aroma of long, medium and short grain rice cultivars were 6%, 10% and 52%respectively.

In long grain rice cultivars, both elongation ratio as well as volume expansion ratio were highly significant and positively correlated with cooking time; hull content was highly significant and negatively correlated with milling outturn; cooking time was highly significant and negatively correlated with head rice recovery as well as alkali spreading value was highly significant and negatively correlated with both cooking time and volume expansion ratio. In medium grain rice cultivars, both cooking time as well as elongation ratio were significant and positively correlated with milling outturn; alkali spreading value was significant and negatively correlated with cooking time; hull content was highly significant and negatively correlated with milling outturn as well as cooking time was highly significant and negatively correlated with head rice recovery. In short grain rice cultivars, volume expansion ratio was highly significant and positively correlated with head rice recovery; elongation ratio was significant and positively correlated with head rice recovery; volume expansion ratio was significant and positively correlated with milling outturn as well as hull content was highly significant and negatively correlated with milling outturn.

Among the local rice cultivars, Joalbagh had the highest phosphorous content (0.43%) but bothJhingasail-2 and Joyna had the lowest phosphorous content (0.20%).Kharmao, Joyna and Betudhan had the highest calcium content (0.06%) but Sadajira Tapl-321 and Murchmut had the lowest calcium content (0.01%). Neda, Pakhisail, Laxmikajol and Dudsail had the highest magnesium content (0.14%) but Kharmao, Nakchi, Kumragoir, Lohasail, Sadamota, Lalbinni, Shamrosh, Gojalgoria, Putidepa, Malagrosa, Chinisagor and Nariabochi had the lowest magnesium content (0.10%). Magoibalam and Motichak had the highest nitrogen content (1.8%) but Kumragoir had the lowest nitrogen content (1.1%).Dadkhani, Laxmikajol and Jirakatari-1 had the highest potassium content (0.30%) but Najirsail had the lowest potassium content (0.13%). Gobcha had the highest sodium content (321 ppm) but Lalmota and Surjyamukhisangla had the lowest sodium content (126 ppm).Harilaxmi, Dudsar Tapal-146, Kalimanik, Nunia, Paharisail, Dholagachha, Hathazi, Ledabinni, Joyna, Lalmota, Uknimadhu, Binniphul, Chunikanai, Sorukamina and Minki had the highest iron content (10 ppm) but Lathamona, Shata, Ganjia and Jhoshua had the lowest iron content (6 ppm) as well as Dudsar Tapal-146, Sadamota, Chamara, Sorukamina had the highest zinc content (20 ppm) but Dudhkalam, Kharmao and Lalbinni had the lowest zinc content (10 ppm).

In all cases of brown rice, results showed that phosphorous content ranged (0.19-0.43)%, (0.17-0.41)% and (0.23-0.39)% respectively in long, medium and short grain rice cultivars;Similarly,Calcium content ranged (0.01-0.06)%, (0.02-0.06)% and (0.01-0.06)%. Magnesium content of these cultivars ranged (0.10-0.14)%, (0.10-0.13)% and (0.10-0.14)%;Nitrogen content ranged (1.1-1.7)%, (1.1-1.8)% and (1.2-1.6)%. Potassium content of these cultivars ranged(0.15-0.26)%, (0.13-0.30)% and (0.16-0.30)%. The amount of sodium content ranged (126-297) ppm, (125-321) ppm and (126-332) ppm; iron content ranged (6-10) ppm, (6-10) ppm and (7-10) ppm as well as zinc content ranged (10-20) ppm, (10-20) ppm and (11-20) ppmin long, medium and short grain rice cultivars respectively.

In long, medium and short grain rice cultivars, local cultivars had higher phosphorous, sodium and iron content than the HYVs. Only long grain local rice cultivars had higher magnesium content than the HYVs. Long grain and medium grain local rice cultivars had higher nitrogen content than the HYVs. Similar potassium content had in medium grain local rice cultivars and HYVs. Similar zinc content had in long grain local rice cultivars and HYVs. Medium grain local rice cultivars had higher zinc content than the HYVs.

Among the rice cultivars, more than 0.4% phosphorous content of long and medium grainwere 5.6% and 6.5%; more than 0.04% calcium content of long,medium and short grain were 39%, 16% and 42%; more than 0.13% magnesium content of long and short grainwere5.5%and 6.45%; more than 1.5% nitrogen contentof long,medium and short grain were11%, 9.7%and 16.1%; more than 0.29% potassium content of medium and short grain were2% and 9.7%; more than 300 ppm sodium content of both medium and short grainwere 3%; more than 9 ppm iron content of long,medium and short grainwere 8.3%, 11% and 16.1% as well as more than 19 ppm zinc content of long,medium and short grainwere 2.78%, 3% and 3% respectively.

In long grain rice cultivars, magnesium content was highly significant and negatively correlated with calcium content; nitrogen content was positively correlated with magnesium content; sodium content was highly significant and negatively correlated with potassium content; zinc content was significant and positively correlated with iron contentas well as zinc content was highly significant and positively correlated with nitrogen content. In medium grain rice cultivars, calcium content was significant and negatively correlated with phosphorous content; potassium content was highly significant and positively correlated with both magnesium andnitrogen content; nitrogen content was significant and positively correlated with magnesium content; zinc content was significant and positively correlated with iron contentas well aszinc content was highly significant and positively correlated with nitrogen content. In short grain rice cultivars,potassium content was significant and positively correlated with both magnesium and nitrogen content; sodium content was significant and negatively correlated with calcium content; nitrogen content was highly significant and positively correlated with magnesium contentas well as zinc content was positively correlated with iron content and nitrogen content.

Carbohydrate, protein, fat, ash, crude fiber and moisture content of selected local rice cultivarsranged (71.18-75.07)%, (7.0-10.7)%, (2.56-3.61)%, (1.02-1.38)%,(0.61-0.99)% and (12.3-13.4)% respectively. Dudkalam had the highest carbohydrate content (75.07%)but Magoibalam had the lowest carbohydrate content(71.18%).Magoibalam had the highest protein content (10.7%)but Dudkalam had the lowest protein content(7.0%).Shithabhog had the highest fat content (3.61%) but Neda had the lowest fat content (2.56%). Ledabinni had the highest ash content (1.38%)but Dudhkalam had the lowest ash content (1.02%). Dudhkalam had the highest crude fiber content(0.99%) but Ledabinni had the lowest crude fiber content(0.61%) as well as Kanaibanshi had the highest moisture content (13.4%) but Neda had the lowest moisture content (12.3%). The mean value of carbohydrate, protein, fat, ash, crude fiber and moisture content for these selected rice cultivars were 73.4%, 8.7%, 3.0%, 1.2%, 0.8% and 12.9% respectively.Protein was highly significant and negatively correlated with carbohydrate. Fat was negatively correlated with carbohydrate and protein. Crude fiber was positively correlated with carbohydrate but negatively correlated with protein and fat. Crude fiber was highly significant and negatively correlated with ash. Moisture was positively correlated with carbohydrate, fat and crude fiber but negatively correlated with protein and ash.

Among all tested rice cultivars, protein content varied from 6.5% to 10.7%. Magoibalam of medium grain rice cultivars had the highest protein content (10.7%) but Kumragoir of medium grain rice cultivars had the lowest protein content (6.5%). The ranges of protein content were (6.5-10.5)%, (6.5-10.7)% and (7.2-9.7)% in long, medium and short grain rice cultivars respectively. In the case of >9% protein content of long, medium and short grain rice cultivars were 14%, 10% and 23%. Medium grain rice cultivars were highly significant and positively correlated with long grain rice cultivars whereas short grain rice cultivars were highly significant and negatively correlated with both long and medium grain rice cultivars on the basis of protein content.

In the case of milling effect on protein content, Depa had the highest protein loss (14.5%) but Neda had the lowest protein loss (8.6%). On the other hand, Ledabinni had the highest protein loss (20%)butboth Dudhkalam and Karailadhan had the lowest protein loss (4%) in the cooking effect on protein content. Protein loss under milling condition had higher than the protein loss under cooking condition of selected local rice cultivars. Protein loss of cooked rice was positively correlated with brown rice protein, milled rice protein and milled rice protein loss but negatively correlated with cooked rice protein.

Albumin,globulin, prolamin and glutelin ranged (7.3-12.2) g/100g, (4.6-6.7) g/100g, (4.0-4.9) g/100g and (78.0-82.8) g/100g respectively forfractionation of proteinamong the ten selected rice cultivars. Magoibalam had the highest albumin but Dudhkalam had the lowest albumin.Athabinni had the highest globulin but both Molladigha and Karailadhan had the lowestglobulin.Dudkalam had the highest prolamin but Neda had the lowestprolamin as well as Molladigha had the highest glutelin but Magoibalam had the lowestglutelin. Albumin was significant and positively correlated with protein content. Among the rice cultivars glutelin showed the highest amount of fractionation ofprotein.

Among the nine selected rice cultivars, the ranges of amino acid composition such as arginine, lysine, alanine, threonine, glycine, valine, serine, proline, isoleucine, leucine, methionine, histidine, phenylalanine, glutamate, aspartate, cystine and tyrosine of the present study were(7.76-10.49) g/100g, (3.34-4.29) g/100g, (5.24-5.79) g/100g, (3.34-3.97) g/100g, (4.51-4.80) g/100g, (5.10-7.25) g/100g, (4.69-5.74) g/100g, (4.73-5.11) g/100g, (4.33) g/100g, (7.94-8.21) g/100g, (2.09-2.23) g/100g, (2.23-2.61) g/100g, (4.93-5.32) g/100g, (17.39-18.30) g/100g, (8.74-9.50) g/100g, (1.36-2.40) g/100g and (4.44-5.83) g/100g respectively. Result showed that glutamatecontent among the amino acid composition was high in rice. Magoibalam, Boylam,Motichak and Molladigha had higher lysine (>4g/100g)at high protein content among the selected rice cultivars. Protein was highly significant and positively correlated with lysine.

The range of in vitro protein digestibility of rice for fifteen selected local rice cultivars were(59-78)%. Magoibalam had the highest in vitro protein digestibility (78%) while both Poushmorich and Depa had the lowest in vitro protein digestibility (59%). In vitro protein digestibility of Motichak, Neda, Molladigha and Boylam were 72%, 68%, 67% and 67% respectively. Protein loss of cooked rice was positively correlated with protein digestibility.

Among the 15 selected local rice cultivars,Athabinni had the highest starch digestibility (68.92%) but Poushmoricha had the lowest starch digestibility (51.57%) at 20 minutes. Athabinni had the highest starch digestibility (83.79%) but Dudkalam had the lowest starch digestibility (62.31%) at 120 minutes. Starch digestibility for selected local rice cultivars at 20 minutes was highly significant and positively correlated with starch digestibility for same cultivars at 0 minute. Starch digestibility for selected local rice cultivars at 120 minutes was negatively correlated with starch digestibility for same cultivars at 0 minute and 20 minutes.

Among all tested rice cultivars, the range of amylose content varied from 5.0% to 29.0%. The ranges of amylose content were (5.0-29.0)%, (5.2-29.0)% and (20.0-27.0)% in long, medium and short grain rice cultivars respectively. Frequency distribution of amylose content showed that 58%, 64.1% and 19% were long, medium and short grain rice cultivars respectivelyat the level of high amylose content; 19%,32.8%and 81% were long, medium and short grain rice cultivars respectivelyat the level of intermediate amylose content; similarly 6% and 1.6% were long and medium grain rice cultivars at the level of low amylose content as well as 17% and 1.6% were long and medium grain rice cultivars at the level of very low amylose content**.** In medium and short grain rice cultivars, amylose content was higher in local cultivars than the HYVs but vice versa of long grain rice cultivars. Amylose content was positively correlated with milled rice lengthbut amylose content was negatively correlated with paddy length among the rice cultivars.

Microsatellite marker (RM190) has identified four classes of alleles varied from 100bp to 120bp in length of the *Waxy* gene. The highest amount of Class-1 allele (100bp) was found in high amylose content rice cultivars. RM190F-GBSSW2R/*AccI* has differentiated G/T single nucleotide polymorphism (SNP) of the *Waxy* gene. Cultivars of <11% amylose had the AGTTATA sequence, which represented very low amylose content rice cultivars. Rest of the cultivars had the AGGTATA sequence, which represented high, intermediate and low amylose content rice cultivars.

Only 3 crosses were made using three photoperiod insensitive cultivars such as Motichak, Magoibalam and Molladigha with BRRI dhan28 and BRRI dhan55. Hence, 3 crosses were confirmed as true hybrid by careful observation of some characters. The plant height of Motichak and BRRI dhan28 were 145 cm and 95 cm. However, the plant height of F_1 plant was 103 cm which showed variation in plant height compared with parent. The percent of protein and amylose content were observed in F_1 generations.In this study, the hybrid vigor of Motichak × BRRI dhan28 showed higher protein content (9.1%) and higher amylose content (26.7%) among the hybrid vigors. The hybrid vigor of Motichak × BRRI dhan28 showed the protein content of 9.1%, which was 5.8% higher than BRRI dhan28 and 13.3% lower than Motichak.The hybrid vigor of Motichak × BRRI dhan28 showed the amylose content of 26.7%, which was 2.7% higher than Motichak and 4.6% lower than BRRI dhan28.

Chapter 1

INTRODUCTION

Rice is indeed a precious gift of Almighty Allah. Archaeological evidence in China, South-East Asia and the Indus Valley suggests that rice must be at least 8,000 years old (Chang, 2003). It is generally considered a semi-aquatic annual grass plant. About 20 species of the genus *Oryza* have been recognized, but nearly all cultivated rice is *Oryza sativa* L. A small amount of *Oryzaglaberrima*, a permanent species, is grown in Africa. So called “wild rice” is more closely related to oatsthan rice (IRRI, StanadardEvalution System., 4th edition, 1996). However, genus *Oryza* is known as *Oryza sativa* in Asian rice and *Oryzaglaberrima*in African rice. The eco-geographic races of *Oryza sativa* are known as Japonica, Javanica and Indica rice. The Indica type of rice cultivars is widely cultivated throughout the world including Bangladesh.

Rice (*Oryza sativa* L.) is the most commonly grown species throughout the world today. It had greater importance to the food security of an increasing number of low-income and food deficit countries on the global food system (FAO, 2004). It has been considered the best staple food among all cereals and is the staple food for over 3 billion people, which is over half of the world’s population (Cantral and Reeves, 2002). Later, Sreepada and Vijayalaxmi, (2013) reported that rice is the staple food andaround 3.5 billion people are consuming the rice. In Asia, it is the predominant staple food for 17 countries including Bangladesh. The importance of rice lies in many spheres- as food, as a source of income and employment (economy) as well as in social development, traditional culture and customs. It is also important in household food security and nutritional diversification (Perez *et al.,* 1987). Rice is the single most dominant crop occupying about 77% of total cropped area in Bangladesh. It contributes about 18% of national GDP and provides 65% of employment. Therefore, in Bangladesh rice production and availability are very much connected with the issue of national food security andwith the issues of livelihood as well as rural development of household farmers involve in rice production.

It is well known that rice production depends not only on variety but also on climate as well as soil status of the regions. Similarly, the nutritional qualities of rice varieties vary not only with the genotypes but also with the agro-ecological zones and cultural practices (Bhattacharya, 1976 and Siscar-Lee *et al.,* 1990). The existence of factors, such as phenotypic variation, weather conditions, fertilizers, soil quality, processing and storage can affect the composition and nutritional value of rice grain (Gomez *et al.,* 1975).

In Bangladesh, rice alone constitutes about 92% of the total food grains produced annually. Of rice, wheat and maize production, Bangladesh is the fourth largest producer and consumer of rice in the world with an annual production ranging between 17 and 18 million metric tons. The rice of Boro, Aus and Aman crops grow in three overlapping season with larger number of different varieties. Among the varieties of rice, Aman rice alone constitutes about 37.74% of total rice production of 33.89 million metric tons (BBS, 2011-2012). So a large number of local rice cultivars are grown in Aman season than the other two seasons. Bangladesh is one of the most densely populated countries and the rice growing area of this country is shrinking gradually.A conservative statistics indicated that about 21% higher productions over the production of 2000 will have to be produced to feed the population by the year 2025 (Bhuiyan *et al.,* 2002).

Moreover, when various types of rice are available in the market, the urban people with higher income group prefer superior grain quality like long slender type translucent grain with higher head rice, Basmati rice, Jasmin rice, aromatic rice, diabetic rice, antioxidant rice, zinc enriched rice, black rice etc. for which they areeven ready to pay premium price. So, consumer′s demand of this areawill be increased day by day. Considering the present status and future demand under changing economic environment, future challenges are to be met through improving yield, grain quality and nutritional value of rice with reducing cost of cultivation for competitive open market where national and international market forces are operating. The market value of rice depends on its physical qualities after the processing. Head rice yield, grain size and shape as well as translucent grain are the most important quality for higher market value. Now a day, higher nutritional quality also increases the market value by adding value.

In future, grain quality will be even more important as very poor consumers, who depend largely on rice for their daily food, demand higher quality rice (JulianoandVillareal, 1993). Among the grain quality characteristics, moisture content is the most important quality criterion for rough rice. Moreover, characteristics of rice grain quality depend on grain size and shape (Owens, 2001). The cultivar, having minimum or no chalkiness, is considered as having good quality grains. On the other hand, grains with chalkiness decrease the rice grain quality and lower the market price. The chalky portion of the grain is not hard enough to resist milling pressure. As a result, the cultivars with chalkiness in the grain tend to break more frequently during milling. Hulled rice kernels are generally milled with a definite degree of milling, depending on the future purpose (Wadsworth, 1994).

Grain length, breadth, translucency, head rice yield, degree of milling and color are influenced by milling process. Microelements seem to be uniformly distributed in the grain that seems to be present in the external layer (pericarp), which is also affected by the milling process (Heinemann *et al.,* 2005). The miller or trader looks for low moisture, variety integrity, higher head rice and milled rice yield. On the other hand, consumers in all the countries prefer higher head rice yield and more translucent fine grain with higher nutritional value. Moreover, cooking quality (sticky and fluffy rice) and eating quality of rice are the most important characteristics for consumers. Rice is starchy food, its amylose content and gelatinization temperature influence the cooking and eating quality of rice. Between these, amylose content alone strongly influences the cooked rice quality. Rice is cooked before consumption. So, cooking qualities of rice has been given top most priority (Tan *et al.,* 1999; FAO, 2004; Jiang *et al.,* 2005 and Dong *et al.,* 2007). Reduced cooking time may be beneficial especially when fuel or energy saving is of concern. Furthermore, high income consumers pay higher premiums for larger number of quality characteristics than low income consumers, reflecting their ability to pay.

Aroma of scented rice is a major character which increases the value of rice in international market (Nayak *et al.,* 2002). The demand for special purpose of aromatic rice has dramatically increased over the past two decades. Most of the trade in aromatic rice is from India, Pakistan and Thailand. Bulk of aromatic rice from India and Pakistan consists of Basmati types, while Thailand is the supplier of Jasmine rice. In Bangladesh, the area of planted aromatic rice varieties is much lower than that of regular rice varieties which is about 23% of total rice area (Baqui *et al*., 1997). Aromatic rice varieties are low yielding due to its traditional plant type which has lodging tendency and low thousand grain weight in Bangladesh.

Understanding the functionalconnections between genes, proteins andmineral ions is one of biology's greatest challenges in the postgenomicera (Lahner*et al*., 2003). Ash content of food gives an idea about the amount of mineral elements present in food. Mineral elements(phosphorous, calcium, magnesium, nitrogen, potassium, sodium, iron and zinc)in rice are most important for human health. They are important components of the enzyme and are critical for thephysical and biochemical reactions. Phosphorous is the second most abundant mineral element in the animal body and (82-85)% presents in bone and teeth (McDowell, 1992). So, it is well known that phosphorous is a major constituent of bone. Calcium is one of the most important another mineral elements in the human body and the major constituent of bone also. It is interesting that rice is the major source of calcium for peoplewhich consuming rice as staple food. Magnesium plays a role in the active transport of calcium and potassium ions across cell membranes, a process that is important to nerve impulse conduction, muscle contraction and normal heart rhythm (Ross*et al*., 2012). Nitrogen supply is often the most important single nutritional factor affecting the growth and yield of rice (Tanaka, 1969). Potassium cations are important in neuron (brain and nerve) function and in influencing osmotic balance between cells and the interstitial fluid with their distribution mediate in all animals by Na^+/K^+-ATPase pump (Campbell and Neil, 1987). The sodium aids in metabolism, specifically in regeneration of phosphoenolpyruvate and synthesis of chlorophyll (Kering, 2008). But higher amount of sodium provides toxicity for body. Micronutrient malnutrition isa major human health problem in the world and five of the mostcommon micronutrient deficiencies are affecting as many as4-5 billion people, especially iron (over 3.5 billion people) andzinc (2.5 billion people) (Zeng *et al*., 2005a).

Rice based food security with nutrition is important in Bangladesh for improving nutritional status of people. Sufficient progress has not yet been achieved in improvement of grain and nutritional quality of rice varieties in this country. The yield contributing and morphological characters as well as physicochemical, milling, cooking and eating properties determine the overall assessment of rice. Similarly, carbohydrate content, protein content, fat content, ash content, crude fiber content, milling and cookingeffect of rice protein, fractionation of protein, amino acid composition as well as digestibility of protein and starch determine the nutritional value of rice. The nutritional value of rice is basically governed by the chemical composition.

Rice provides energy, protein and vitamins for half of the world's population (Nguyen, 2010 and Tiwari *et al.,* 2011). Most of the Asian as well as Bangladeshi people consume milled rice as the principal source of energy. However, the nutritional status of population for the developing world is affected by several factors including population density, inability of most of the population to grow or buy enough staples for its own use, postharvest operation (threshing, drying, storing, milling and cooking process), decreasing rice growing land and economies of scale in agricultural research that decrease the diversity of food supply. For this reason, under nutrition is one of the most significant factors for the developing country. All children require sufficient protein every day to meet their potential growth and development. Only, 20% of the world's people are rich enough to have access to nutritious diet. But 850 million people worldwide are affected by protein energy malnutrition. It is estimated that under nutrition is the cause of half of all the cases of child mortality. The nutritional value depends on the total quantity and quality of protein. Quality of rice protein is good among the cereal crops.

Albumin and globulin are found mostly in the outer layer of brown rice and less in the inner layer of milled rice. Prolamin and glutelin are considered to be the storage proteins of rice. They also exist in the outer layer and the inner layer of milled rice. Thus, the fractionation of protein of bran and germ differs greatly from that of milled rice. Rice prolamin is characterized by low protein purity (Palmiano*et al*., 1968). Moreover, the nutritional quality of proteins is principally governed by its amino acid composition (Padhye and Salunkhe, 1979).Food grains like rice comprise essential amino acids such as lysine, methionine, tryptophan, valine, leucine and isoleucine which are important for human physiological functions and cannot be synthesize by the human body. Amino acid analysis showed lysine was the first limiting essential amino acid in cereal proteins. Lysine content had (3.8g/100g) in rice, (2.5g/100g) in maize and (2.3g/100g) in wheat among the cereal proteins (Eggum, 1979). Amino acid analysis of four protein fractions of milled rice showed that albumin had the highest lysine content followed by gluteline, globulin and prolamin respectively (Chavan and Duggal, 1978). In Bangladesh, rice is produced efficiently and no other food product can compare it withrespect to supplying nutrients. As a result, rice is desirable food for poor people due to better understanding of the nutritional value.

Waxy gene encodes granule-bound starch synthase (GBSS) that is responsible for amylose synthesis in rice endosperm. A study identified 59.3% of the variation in apparent amylose content by RM190 (Wan *et al*., 2007). The *Wxa* allele contains AG<u>G</u>TATA sequence, which is responsible for intermediate to high amylose content. On the other hand, *Wxb* allele contains AG<u>T</u>TATA sequence, which is responsible for low amylose content.Microsatellite marker RM190F-R and RM190F-GBSSW2R with restriction enzyme (*AccI*) are found close linkage to the *Waxy* gene identify. So these microsatellite marker and restriction enzyme are the most effective for early selection of amylose status than the conventional methods.

Breeders paid more attention to increase grain yield but less emphasis had been given for improving grain and nutritional quality of rice variety at the beginning. Grain yield and protein content of rice were generally correlated negatively (Govindaswami and Ghosh, 1974). Now a day, breeder pay more attention to generate breeding population with high protein, high amylose and high thousand grain weight coupled with fine grain, earliness, good plant type and yield potential into modern genetic background. Thinking about low income group, nutritional value of rice is a prime importance for researchers. So, documentation for high nutrient content of rice cultivars allows breeders to identify rice varieties with superior grain and nutritional qualities.

There are about 12,000 local rice cultivars in Bangladesh (Hamid *et al.,* 1982). Some of these cultivars have excellent grain and eating qualities. Some of them are popular but they have low grain yield. Scientists have been working for a long time on improving the yield, grain and quality of rice using different techniques like hybridization, mutation breeding and tissue culture. To fulfill the purpose of these technique different criteria of rice cultivars could be selected first after screening.

Among the HYVs of rice- 22 yielding 6-9 t/ha, 23 having fine grain, 5 with aroma and 1 zinc enriched variety- have been developed by hybridization (Adhunicdhanerchash, BRRI, 2013). Up to 2016, scientists of Bangladesh Rice Research Institute (BRRI) have developed 80 modern high yield rice varieties (76 inbred and 4 hybrid) and recommended 22 local improved rice varieties for cultivation. These varieties are widely cultivated throughout the country. Now a day, farmers are very keen to cultivate modern high yield varieties. With the introduction of modern high yield varieties, some of the popular local cultivars with superior grain quality characters are being replaced. At the beginning, research efforts had been focused mainly on grain yield with a little emphasis on the quality. There were studies on the quality characteristics of modern high yielding rice varieties (Biswas *et al.*, 1992 and Siddiquee *et al.,* 2002) and very few studies were on the local germplasm cultivars. Now scientists have made strategy to develop high yielding variety with superior grain and nutritional quality. With this view, evaluation of rice germplasm has become an important factor for developing high yield varieties with superior grain and nutritional quality. Since, the local cultivars were nutritionally superior (Diako *et al.,* 2011).

Hypothesis

Hypothesis for the mechanism is to identify superior quality rice germplasm cultivars and nutritional quality as well as also the molecular basis of important traits for developing improved high yielding varieties. The study has been emphasized on the followings:

- Higher yield, long and medium slender with translucent grain for identifying promising rice.
- Milling quality with higher milling outturn and higher head rice recovery for identifying superior rice cultivars.
- Higher elongation, higher volume expansion and intermediate gelatinization temperature of rice cultivars indicate superior quality.
- Mineral contents of local rice cultivars are higher than the HYVs.
- High protein content, high amylose content, amino acid composition, higher protein and starch digestibility represent superior nutritional quality.
- Amylose content is one of the most important traits that govern the eating, cooking and processing quality of rice and ultimately determines its market price. The *Waxy* gene encodes a granule-bound starch synthase that is responsible for amylose content in rice endosperm.
- Grain and nutritional quality of rice can be improved through hybridization.

These factors may contribute to identify the rice varieties with superior grain quality as well as nutritional quality.

General objective

The aim of the present study was to identify superior quality rice germplasm based on agronomic and morphological characters, physicochemical properties, milling and cooking properties, mineral elements as well asnutritional quality. The study emphasized on efficacy determination of SSR marker and restriction enzyme digestion for discrimination of amylose status of Bangladeshi rice cultivars. It was very important for assessment to generate breeding population for high nutritional quality coupled with fine grain, earliness, good plant type and yield potential into modern genetic background through hybridization.

Specific objectives

The specific objectives of the study were-

- To investigate the physical properties of rough and brown rice of the collected samples (hull color, awn status, panicle type, pericarp color and thousand grain weight).
- To investigate the milling performance of rough rice of the cultivar during milling (milled rice outturn and head rice recovery).
- To evaluate the physical properties of milled rice (grain length, grain breadth, grain size and shape, appearance as well as grain chalkiness), chemical and eating quality of the rice grain (amylose content, gelatinization temperature, elongation ratio, volume expansion ratio, aroma, carbohydrate content, ash content, crude fiber content, fat content, protein content, fractionation ofprotein and amino acid composition) as well as in vitro starch and protein digestibility for rice cultivars having superior grain and nutritional quality.
- To identify rice cultivars with high mineral contents such as phosphorous, calcium, magnesium, nitrogen, potassium, sodium, iron and zinc.
- Evaluation of genetic diversity of the *Wax*y gene in selected rice cultivars by using microsatellite marker and cleaved amplified polymorphic sequence marker.
- Evaluation of F_1 hybridization and its confirmation on the basis of morphological and nutritional performances.

Considering the physicochemical and nutritional parameters, promising rice cultivars will be selected as potential candidate for breeding.

Chapter 2

REVIEW OF LITERATURE

2.1 Agronomic characters

Grain yield of rice cultivars is determined by thousand grain weight, number of tiller/hill, number of panicle/hill, panicle length, number of spikelets/panicle and percent of filled grains. Morales, (1986) suggested that thousand grain weight and number of grains/panicle might be considered important criteria for increasing yield/unit area. Thousand grain weight was determined by grain size and degree of grain filling. The grain size was a stable cultivar's characteristic determined before anthesis and it was rigidly controlled by size of the hull (Samonte *et al*., 1998). Excessive tillering lead to high tiller abortion, poor grain setting, small panicle size and further reduced grain yield (Peng *et al.*, 1994 and Ahmad *et al.*, 2005). While Wang, (2007) stated that the high panicle bearing tiller rate was partly responsible for high grain yield of rice. But Ibrahim *et al*., (1990) found that the number of productive tillers was the most reliable character to use in selecting genotypes. Because panicle number per plant was determined by effective tiller produced and that which survive for grain production. Juliana, (2012) reported that the panicle length was an important trait which contributes to yield in rice because it determined the number of spikelets that would be produced. Feil, (1992) reported that among the components of grain yield of a cereal crop, the number of spikelets per panicle appeared to be the predominant or key character to the development of high yielding cultivars. In another study, Moeljopawiro, (1989) reported that grains/panicle was the yield determining component with the greatest effect. Deosarkar *et al*., (1989) and Mehetre *et al.,* (1994) reported that significant positive associations between grain yield per plant and number of grains per panicle. While, Mehetre *et al*., (1994) reported that the filled grains/panicle was an important yield contributing character. Similarly, Yoshida and Parao, (1976) reported that filled spikelet was an important yield contributing factor. In addition, Wada, (1969) reported that the percentage of filled spikelets often decreased though the number of spikelets per square meter increased.

Prasad *et al*., (1988) observed positive correlations between grains yield/plant and yield components: thousand grain weight, total spikelets/panicle and fertile grains/panicle. Furthermore, Iftekharuddaula *et al*., (2001) reported that from the correlation and path study it might be concluded that number of tiller per hill, panicle length and number of spikeletsper panicle were the most important characters that contributed directly to seed yield per hill. Grafius, (1960) suggested that individual yield component might contribute valuable information in breeding for yield. So, a genotype with higher magnitude of these traits could be either selected from existing genotypes or evolved by breeding program for genetic improvement of yield in rice.

BRRI, (2000) reported that a considerable variation in yield and yield contributing characters for 17 BRRI released varieties and an exotic genotype (Anamika) under similar cultural practices during Boro season. BR16 produced the highest grain yield followed by BR26, BR15, BRRI dhan29, BR3, BR12 and BRRI dhan28 ranging from 6.06 t/ha to 6.98 t/ha. BRRI dhan36, BR19, Anamika and BR2 produced more than 5 t/ha. ButBR6 produced the lowest grain yield of 4.39 t/ha and the rest of the varieties had between 4.89 t/ha to 4.92 t/ha grain yield. Moreover, spikelets number/m^2 varied from 29,060 to 58,495 among the varieties. Diako *et al*., (2011) reported that values of thousand grain weight of rice between 20 g and 30 g were considered good while those less damaged and unfilled grains. BRRI, (2006) reported that the growth duration of the salt tolerance rice varieties varied from 92 days to 98 days and 16 selected lines of rice varieties varied from 126 days to 151 days in T. Aman season. Mondal *et al*., (1987) reported that increasing rates of nitrogen (N), from 40 kg N/ha to 160 kg N/ha increased the number of panicle per unit area. Oka, (1958) reported that rice plant varied in height from dwarf mutants (only 3 m to 4 m tall) to floating varieties (more than 7 m tall). The great majority of commercial varieties ranged from 1 m to 2 m in plant height.

The loss of yield can occur at any point during harvesting, threshing, cleaning, drying, storage and transportation. (10-37)% of total rice production in an estimation was lost due to post-harvest factors (Saunders and Betschart, 1979). Yield contributing factors are highly affected by such factors as climate, weather conditions, soil, cultural management, variety and nutrient supply. Understanding their interrelationships is a key to improvement in rice grain yield.

2.2 Morphological and physical properties

Panicle threshability: Panicle threshability is an important characteristic for most breeding programs. Easy threshability of panicle starts shuttering in the rice filled before harvesting. So, easy shatteringvarieties are not acceptable to any of the farmers because they cause severe yield loss no matter what type of harvesting is practiced reported by Ji *et al*., (2006).

Varieties with moderate shattering are favored where rice is harvested by large combine harvester-threshers, while harvesting using a small head-feeding combine is the most efficient when hard-shattering to non-shattering varieties are used (Kobayashi 1990). Kumar and Shadakshari, (2011) reported that KHP-10 had intermediate panicle threshability.

Panicle type: Panicle type is another important characteristic for rice cultivars. In China, compact panicle cultivars dominate japonica rice production. These cultivars had more spikelets per unit length of panicle to increase spikelet number per panicle (Wang *et al.*, 2008). According to grain density of panicle, japonica rice can be grouped into three types (Liu *et al.*, 2012): compact panicle (CP), loose panicle (LP) and intermediate panicle (IP). Additionally, Wang *et al.*, (2008) reported that compact panicle cultivars had large variation of physiochemical traits including grain length, width, length-width ratio, chalky grain rate and amylose content of the grains on the rice panicle as compared with loose panicle cultivars. Kumar and Shadakshari, (2011) reported that KHP-10 had semicompact panicle type.

Awn status: Presence of awn on the spikelets of the panicle is distributed in different patterns. Awning is considered a nuisance during milling but it has been reported to play a role in preventing birds from sucking the milk-stage of rice during grain filling by many farmers. Awn creates a problematic view in plant breeding program. Moreover, breeders may select the short-awned types as a compromise during cultivar development. Asif *et al.*, (2009) reported that among the cultivars, 126 had awnless, 15 had short and partly awned, 4 had short and fully awned, 1 had long and partly awned as well as 4 had long and fully awned.

Hull color: Hull color is not regarded as a factor when the variety is subjected to producing regular white milled rice of non-parboiled but it is a factor for parboiled rice. A light color hull generates light colored parboiled rice which is preferred over the dark colored varieties that produces dark colored parboiled rice (USDA, 1982;Webb, 1985 and Luh, 1991). The color of paddy is normally a shade of yellow or golden with minor variation from light to a little darker and straw color as well as some are black, black-golden mixed and purple paddy color. But a few rare varieties have some strong dark or even blackish color. Golden hull color of the paddy is the best choice of farmers in Bangladesh.

Pericarp color: Inside the hull as well as covering the endosperm and embryo of the mature rice grain are three distinct layers of crushed cells that make up the caryopsis (brown rice) coat: pericarp, seed coat and nucellus. The pericarp is the mature ripened ovary wall, which undergoes extensive degeneration during caryopsis development (Bechtel and Pomeranz, 1980). The thickness of this layer is about 10μm. White rice is widely accepted and generally favored by most consumers and have been under strong selection from thousands of years. Even though white rice is generally consumed but there are many specific cultivars of rice that have color pigments, such as black and red. Pigments in colored rice are usually in the pericarp or the seed coat, which explains varietal differences in pigment retention on milling. Red rice has red pericarp or seed coat or both (Juliano, 1972). Brown rice is named for its brown pericarp. However, the red colored pericarp in wild rice defines resistance to various biotic stresses and is used in many places for medicinal reasons (Sweeney and McCouch, 2007). China, Korea, Japan and many other countries in Southeast Asia have traditionally consumed pigmented rice (*Oryza sativa* L.). Pigmented rice was reported to have a greater antioxidative capacity than the white rice (Choi *et al.,* 2007). The red, black, purple and pink pigments in rice are anthocyanins present in the pericarp (Ryu *et al.,* 1998; Ichikawa *et al.,* 2001; Wang *et al.,* 2003; Abdel-Aal *et al.,* 2006 and Patindol *et al.,* 2006). Anthocyanins have anti-oxidant properties which have positive human health benefits including suppression of tumour cell growth (Koide *et al.,* 1996). The red color of red rice in Japan is now being used for making colored noodles, cakes and alcoholic beverages (Patindol *et al.,* 2006). At present many colored rice varieties are sold as a blend with common varieties.

Size and shape: Size and shape is the most important grain characteristics that dictate the marketability and commercial viability of rice (Khush *et al.,* 1979). Generally, consumers in the tropics and sub tropics prefer long slender and medium slender grains and in temperate areas, short bold and roundish grains are preferred (Khush, 2001). In India the famous aromatic rice is Basmati, which has the most extra-long slender grain size and shape reported by Kamath *et al.,*(2008). So, preferences for grain size and shape vary from country to country and culture to culture (Juliano, 1985a;Cruz and Khush, 2000 as well as Zhou *et al*., 2002a). In India, grains are classified considering length, breadth and length breadth ratio into long slender (length 6.0 mm and above, length/breath ratio 3.0 and above), long bold (length 6.0 mm and above, L/B ratio less than 3.0), medium slender (length less than 6 mm, L/B ratio 2.5 to 3.0), short slender (length less than 6 mm and L/B ratio 3 and above) and short bold (length less than 6mm, L/B ratio less than 3.0) reported by (Ramiah, 1969).

In the grain form, indicarice is slender shaped longer grain and japonicarice is short grained with bold and thick shaped (Singh *et al*., 2000 and Brandolini *et al*., 2006). Slender grains look finer in shape reported by Hasiba *et al.*,(2006). Matthews *et al.,* (1970) and Jongkaewwattana *et al.,* (1993) noted that medium-grain rice was more resistant to cracking than long-grain rice during milling, probably due to its more rounded and thicker grain shape compared to the slender-shaped grain of long-grain rice. Slender rice varieties have been found to uptake greater amounts of water during cooking than short and round varieties (Bergman *et al.*,2004). In U.S.A, long grains have been selected for a slender shape that cooks dry and fluffy. Medium grains are selected for a medium and slightly bolder that cooks moist and slightly sticky. Short grains have been selected for a bold rounder shape that also cooks moist and slightly sticky (Moldenhauer *et al*., 2004).

Chalkiness: Grain chalkiness is a complex phenomenon, which produces by the influence of both genetic and environmental factors. The endosperm of some non *Waxy* rice grains often have areas which are opaque compared to the translucent appearance. These opaque areas are traditionally called chalk or grains chalkiness, which are incompletely filled grains. Chalkiness is usually induced and is higher when plants are exposed to high temperatures during the grain-filling stage. The starch granules in the translucent parts of the rice grain are generally bigger and more tightly packed than the smaller, loosely packed granules found in the chalky areas of the grain (Lisle *et al.,* 2000). Chalkiness reduces grain resistance to milling due to weak chalky grains and tends to break in milling. An exception to this is in parboiled rice, where this process tends to strengthen the grains to milling. Commercial markets determine the value of rice on the basis of the level of chalkiness and the proportion of broken grains. Chalky grains contribute to both of these properties (Fitzgerald *et al.,* 2009). Additionally, chalky grains also have slightly lower amylose content reported by Kim *et al.*,(2000).

There are major two types of chalky rice, white-belly and white-core rice kernel which are cultivated in China (Qiao *et al.,* 2011).Ikehashi and Khush, (1979) reported that the chalky grains in rice are usually classified into white center or white core, white belly, milky white and opaque. There is a clear distinction between the origin of white core and white belly. White core chalkiness seems to be genetically controlled, since some varieties habitually have white core grains while others do not. For instance, Basmati rice and their derivatives generally have roughly 50% of the grains with a small white core. In fact that is considered one of the characteristic properties of Basmati rice (Kamath *et al.,* 2008). On the other hand, chalkiness is more frequently found in bold shape grain than in slender shape grain of comparable length (Nakatat and Jackson, 1973).

Appearance: Rice performance quality is determined by observing the appearance of the endosperm. Traditionally, rice appearance is evaluated by eye or microscope for measuring grain dimensions (Ikehashi and Khush, 1979). Grain appearance is the function of endosperm opacity: amount of chalkiness either in the dorsal (white belly) or in the center side of the grain (white center) as well as condition of eye: grain size and shape, uniformity, color and damaged or imperfect grains (Khush *et al.,* 1979). The eye is the pit left by the embryo in milling. The milled rice with damaged eye attained poor appearance and lower market price. Furthermore, chalkiness is a major trait for evaluation of grain appearance that affects consumer acceptance of rice. It also invariably detracts overall appearance and generally results in lower milling yield (Yamakawa *et al.,* 2007).

Length, breadth and L/B ratio of paddy, brown rice and milled rice: Paddy comprises various types of kernels. Chaudhari *et al.,* (2014) reported that among 121 rice cultivars 53 had extra-long, 46 had long, 14 had medium and 8 had short seed length. Some high yielding varieties from India had 5.2 mm to 6.8 mm in length and 1.9 mm to 2.5 mm in breadth. Wide variation in L/B ratio from 2.21 to 4.12, 2.62 to 4.55 and from 1.5 to 3.5 have been reported by Singh *et al.,* (2005) and Khatoon *et al.,* (2007). Sareepuang *et al.,* (2008) found that the length and width of parboiled rice varied from 7.0 mm to 9.0 mm and 2.02 mm to 2.06 mm respectively. In fact, most of rice varieties are medium grains but some are long and small grains. Long grains are expected as premium quality of rice with strong demand in the world market. Moreover, long grain aromatic rice is highly popular and is the most expensive in the rice international market (Cruz and Khush, 2000). For instance, Middle East consumers prefer long grain, well milled rice with strong aroma; whereas, European communities prefer long grain rice with no scent. In West Africa, long grain and aromatic rice are used with sauces while short and medium grain rice are used in porridge mixed with sugar, salt and milk as well as broken rice is used in Senegal, Gambia and Mali as fried rice (Efferson, 1985). On the other hand, it is true that some small and medium grained aromatic rice possess excellent aroma and other quality traits like elongation after cooking, taste etc. These could be excellent sources for improving quality in high yielding varieties. Long grain associates with high amylose (>25%) and remains separate when cooked. On the other hand, medium grain rice has relatively low amylose (16-18)% and stickier upon cooking (Webb, 1985; Blakeney, 1996 as well as Evers and Millar, 2002).

Thinner kernels usually contain higher protein, lipids, vitamins, and lower starch contents than thicker kernels (Matthews *et al.*, 1981).

2.3 Milling and cooking properties

Milling quality: Milling is an important quality in postharvest operation. Individual rice varieties having their own milling parameters, the conditions under which a crop is grown, harvested, dried, stored and milled, will affect milling quality and contribute to the grade of the milled product. The condition of the rice on arrival at the mill had a decisive effect on the quality of the milled product (Angladette, 1963). Since, milling quality is an important factor for determining the income of millers and farmers. The value of paddy is directly related to its milling quality and the prevailing market demands. So, rice millers prefer cultivars with high milling outturn and high head rice recovery. Milling quality of rice can cause reductionby diseases such as rice blast or sheath blight (Candole *et al.*, 2000).

Milling outturn: Milling outturn is the measure of rough rice performance during milling. So, rice millers prefer varieties with high milling outturn. The milling outturn of aromatic rice ranged from (70-72)% reported by Biswas *et al.*, (1992). Milling yield of rice cultivars depends on hull thickness, size and shape of kernel as well as moisture content of the grain (Adair *et al.*, 1973). Esmay *et al.*, (1979) reported that milling causes relative changes in proximate composition and the degree of milling determines the amount of nutrient in the residual milled rice.White rice quality is increased with the number of times the grain is passed through the mill and more starch layers are removed. The milling yield of rice depended on the milling system used and India, suffering from a serious shortage of rice then, could increase her rice availability substantially, even with her current output of paddy, simply by replacing her age-old rice-milling system with modern equipment and systems (Faulkner *et al.*, 1963).

Head rice recovery: Head rice (at least 75% the length of whole grain) was separated from the broken (<75% the length of whole grain) reported by FAO, (1972b). Unnevehr *et al.*, (1992) reported that head rice was more valuable than broken and consumer preferred high head rice content with more translucent rice. Applying nitrogen fertilizer close to booting can enhanced photosynthetic capacity during the grain filling period, leading to an increase in head rice yield (Japanese Food Agency, 1998). Furthermore, Seetanun and De Datta (1973) reported that topdressing with nitrogen at flowering increased head rice yield of

IR8,IR20, RD1 and C4-63 as well as this was associated with higher protein content in milled rice.

For milling and polishing, using lower weights for a longer duration could increase head rice yield without changing the whiteness (Pan *et al.*, 2007). The decrease in head rice yield with milling was attributed to the removal of a greater amount of bran as well as due to the increased breakage of weak rice kernels with longer milling durations (Siebenmorgen and Sun, 1994 as well as Saleh and Meullenet, 2007). Bhattacharya and Subba Rao, (1966) stated that most of the breakage occurred at the earliest stage and increased little with continual milling. Similarly, Bhatia, (1969) concluded that on average 70-80% of the total breakage occurred during the first five seconds of milling. Matthews and Spadaro, (1976) found that breakage of milled rice was generally greater for thinner kernel fractions. Sun and Siebenmorgen, (1993) reported that head rice yield increased with increasing thickness, reached a maximum and then decreased. Siebenmorgen *et al.*, (2007) reported that head rice yield typically varied with moisture content at which point rice was harvested. Under Arkansas weather conditions, the harvested moisture content at which head rice yield was maximum (approximately 19% to 21% for long-grain and 22% to 24% for medium-grain cultivars).

Hull content: The mature rice grain is harvested as a covered grain which is made of tough siliceous hull (husk). It composed of two parts, lemma and palea. These two parts are held together by two hook-like structures. The rice hull provides protection to the brown rice from fungal infestation and protection from the outside injury. The tightness of the two parts of the hull has been related to the grain's resistance to insect infestation during storage and well protection. On average, rough rice produced 25% hull, 10% bran and 65% white rice (Saunders and Betschart, 1979). Amount of husk of paddy varied from a low of 14.6% (Sadanandeswara Rao and Bhattacharya, 1977) to a high of 26.0% (Juliano *et al.*, 1964).

Cooking quality: Grain quality of rice is reported to be influenced by various physicochemical characteristics that determine the cooking behavior (Bocevska *et al.,* 2009 and Moongngarm *et al.,* 2010). Cooking characters are the grain elongation, gelatinization temperature and aroma (Khush *et al.,* 1979).Similarly, Little *et al.,* (1958) stated that the gelatinization temperature is a major rice trait, which is directly related to its cooking and eating quality. On the other hand amylose, amylopectin structure and protein composition explained the difference in cooking quality of rice (Lisle *et al.,* 2000). Cooking and eating properties of rice are strongly influenced by grain shape and width of rice (McKenzie *et* *al.*,1983). Various studies showed that Ghanaian consumers have a higher preference for imported rice because of its perceived higher cooking quality (Tomlins *et al.,* 2005 and Diako *et al.,* 2011).

Alkali spreading value: Alkali spreading value influencesthe gelatinization temperature.Low alkali spreading values corresponded to high gelatinization temperature. High air temperature after flowering raises the gelatinization temperature (which lowers grain quality) and low air temperature reduces it (Jennings *et al.,* 1979). Gelatinization temperature is controlled by a few genetic factors and is highly heritable and screening can be done effectively in the early generations. When crossed with tropical indica, many japonicas (low gelatinization temperature) and some US (intermediate gelatinization temperature) parents produce a moderate proportion of high gelatinization temperature segregates (Jennings *et al.,* 1979).Perez and Juliano, (1979) found low gelatinization temperature among the *Waxy* rice. Medium gelatinization temperature has been observed in short and medium grain cultivars (Fan *et al.,* 1999). Normand *et al.,* (1989) reported that gelatinization temperatures for long, medium and short varieties decreased with decreasing grain length.

Cooking time: Cooking time of the rice depends on coarseness, protein content, amylose content and finally on its starch gelatinization temperature. Moreover, small and slender grains cook faster than big and round grains. Yadav and Jindal, (2007) reported that high protein rice requires longer cooking time than low protein rice of their selected lines of rice samples. Longer cooking duration resulted in greater moisture content of cooked rice producing softer rice. As a result, high protein or high gelatinization temperature of rice was thought to need a longer cooking time and more amount of water to cook satisfactorily. Brown rice takes longer cooking time than the milled rice during cooking. The rice varieties which had higher amylose content required a shorter cooking time (Thomas *et al.,* 2013). During cooking elongation of rice might be dependent on variety and duration of storage of rice (Madan and Bhat, 1984). Pre-soaking of basmati rice before cooking in excess water reduced the time of cooking from 20 minutes to 10 minutes and increased the dimensional changes due to cooking (Hirannaiah *et al.,* 2001).

Elongation ratio: Some varieties show extreme elongation along the long axis on cooking. Arrangement of cell may be a factor for such expansion characteristics. These cells in the grain may produce many fissures that form during presoaking, which increase grain elongation along the long axis on cooking. They observed that the rice grain developed transverse cracks upon soaking. The cracks formed within several minutes in raw milled rice but required up to 1-2 hours in the case of parboiled rice (Desikachar and Subrahmanyan, 1961). Grains elongated considerably more when cooked after presoaking compared with direct cooking. Sowbhagya and Ali, (1991) confirmed the above findings with detailed data. A relatively high kernel elongation during cooking is considered an important desirable characteristic of the Basmati group of rice (Kamath *et al.,* 2008). Maximum elongation ratio was observed in Basmati rice 1.77, followed by brown rice 1.68.A simplified method assessed in (1982-1983) in 16 countries, involved five samples were showed variation in grain elongation (Juliano and perez, 1984).

Elongation of rice can be influenced by both the L/B ratio and amylose contents (Singh *et al.,* 2005 and Danbana *et al.,* 2011). Additionally, Yadav *et al.,* (2007) reported that the elongation ratio of rice kernels was observed to show highly significant and positive correlation with amylose content. The elongation ratio of cooked kernels showed a highly significant and positive correlation with L/B ratio of raw kernels. Earlier, a strong positive correlation has also been reported between amylose content and elongation of rice (Nayak *et al.,* 2003).

Volume expansion ratio: Cooked rice of high amylose rice shows high volume expansion having non glossy but white in color. On the other hand, *Waxy* rice expanded less during cooking but cooked *Waxy* rice is very glossy with least white color (Juliano *et al.,* 1965). Volume expansion influences many of the starch properties of rice (Juliano, 1979). Additionally, volume expansion was correlated directly with amylose content (Juliano, 1985b). Working class people who do not care whether the expansion is lengthwise or breadthwise but urban people who prefer the varieties that expand more in lengthwise than in breadthwise (Choudhury, 1979).

Aroma: The aromatic varieties of rice are usually cultivated in Aman season. Some varieties invariably possess a strong aroma, which is a unique intrinsic quality of all aromatic varieties of Bangladesh. Among them three popular varieties, Chinigura, Kalijira and Kataribhog were widely cultivated and marketed. Both Kalijira and Chinigura mainly were grown in the Rajshahi region, whereas Kataribhog in the Dinajpur region. Farmers cultivate aromatic rice not only for home consumption of their special dishes but also for commercial purposes. In spite of non-aromatic rice varieties (mostly modem varieties) give a significantly higher yield compared to aromatic varieties, in most cases profit of aromatic varieties are much higher than that of coarse rice (Baqui *et al.,* 1997). The demand for special purpose of aromatic rice has dramatically increased over the past two decades. The main aromatic (volatile) compound, 2-acetyl-1- pyrroline (2AP) was detected in one of the famous aromatic rice Khaw Dawk Mali-105 (Laksanalamai and Ilangantileke, 1993 as well as Bourgis *et al.,* 2008). Furthermore, Weber *et al.,* (2000) stated that 2-acetyl-1- pyrroline (2AP) content of aromatic rice is 15 times greater than that of non-aromatic rice. Itani and Fushimi, (1996) reported that retention of the volatile compound is affected by temperature during grain development, drying and storage.

2.4 Mineral elements

Minerals are inorganic elements in rice. Rice varieties are good sources of minerals which can contribute to the recommended dietary allowance (Heinemann *et al.,* 2005). Minerals are constituents of the bone, teeth, soft tissue, muscle, blood and nerve cells. They are vital for overall mental and physical well-being. Minerals act as cofactors for many biological reactions within the body, including muscle contraction, neuro-transmission, production of hormones, digestion and utilization of nutrients (Champe and Harvey, 1994).

Minerals are randomly distributed in a brown rice grain. Mineral contents in a brown rice grain tend to decrease toward the endosperm. So, endosperm contains much less minerals than germ and the outer bran layer fractions. The content of Ca, P, Fe, Na and K each of these elements is higher in the germ (embryo) and the bran layer but lower in the endosperm. K, P and Mg are more abundant in the aleurone layer reported by (Kubo, 1960). The colored rice is a source of minerals. Black rice has relatively high mineral content including Fe reported by (Anon, 2009). Chinese researchers (Zhao *et al.,* 1993) stated that red rice has high level of Fe and Zn, while purple or black rice is reach in numerous trace elements Mg, Ca and Mo. The mineral content and bioavailability of different rice were evaluated and reported in a review paper and it was concluded that Zn, Fe, Ca, Mn and Cu were highest in black rice but lowest in glutinous rice (Meng *et al.,* 2005). Minerals like Ca, Mg and P were present along with some traces of Fe, Cu, Zn and Mn (Yousaf, 1992). High levels of K, Ca, and P have also been found in rice bran in Ghana reported by (Amissah *et al.,* 2003). The S, P, Mg, Zn and Fe content in three wild rice species was 30%-58% higher than that of the six cultivars (Cheng *et al.,* 2005). According to other studies carried out, the mineral content (P, K, Ca, Mg, Fe, Zn and Cu) in brown rice from Vietnamese and Australian rice is relatively lower than that of Yunnan rice (Yasui and Shindoh, 2000). Dikeman *et al*., (1981) investigated four indica rice varieties namely Irri-6, KS-282, Basmati 2000 and Basmati Super for their mineral profile. Analysis of investigated varieties revealed the contents of minerals such as Na, K, Fe and Zn to be significantly higher in brown rice than those in white rice. There were no significant differences in the levels of minerals; Ca, Fe, Mg and P in raw, cooked and soaked ofada and aroso rice (Osaretin *et al.*, 2007). Although, some heavy metals, such as Cu and Zn have known functions as micronutrients in plants (Sharma, 2006), they become toxic at high levels (Pandey, 2008). Mineral content is greatly influenced by the cultivation conditions including fertilization and soil condition. The mineral composition of rice grain largely depends on the availability of soil nutrients (Juliano and Bechtel, 1985).

Phosphorus: Phosphorous is commonly present in all globoids of rice reported by Wada and Lott, (1997). In rice phosphorous was concentrated more in the outermost layer and showed a steep fall in concentration followed by a further gradual decline in the subsequent inner layers (Doesthale *et al.*, 1979). On 5% milling of the grain, total phosphorous was lost to the extent of 51% and additional loss on 10% was smaller in amount. The phosphorous content for rice was significant varietal variation, which was more pronounced in the local varieties (Adu-Kwarteng *et al.*, 2003). There are many factors in diets with interfering phosphorous absorption. Among these, intakes of large quantity of Fe, Al and Mn decrease absorption of phosphorous by forming insoluble phosphates (Guillot *et al.*, 1982). At the standard protein intake, even with higher phosphorous levels in the brown rice diet, absorption rates of phosphorous was still significantly lower for the brown rice diet (Miyoshi *et al.*, 1987b). It has been reported by many researchers that phosphorous deficiency has a significant influence on leaf photosynthesis and carbon metabolisms in plants (Rao, 1996).

Calcium: Calcium was detected mainly in globoids of the aleurone layer of rice (Wada and Lott, 1997). Doesthale *et al.*, (1979) reported that the degree of polishing determined the magnitude of loss in parboiled rice. They found that the percentage of losses of calcium on 5% and 10% milling of raw rice were 36% and 57% respectively. Additional loss on 10% milling was smaller in magnitude. Adu-Kwarteng *et al.*, (2003) reported that the calcium contents of new rice varieties (breeding lines) with that of local varieties grown by farmers in Ghana and also reported that the calcium levels ranged between 202.7µg/g and 267.0µg/g for the 20 varieties, the local varieties had appreciably higher levels relative to the breeding lines.

Magnesium: Magnesium is commonly present in all globoids reported by Wada and Lott, (1997). It is a cofactor in more than 300 enzyme systems that regulate diverse biochemical reactions in the body, including protein synthesis, muscle and nerve function, blood glucose control and blood pressure regulation reported by Coates *et al.,* (2010) and Ross *et al*., (2012).

Nitrogen: A vast research work has been done in various parts of the world on the nitrogen nutrition of rice. Among the nutrient elements derived from soil, the rice plant requires nitrogen in the greatest amount (Thenababu, 1972). Similarly, Murayama (1973) reported that the rice plant must absorb larger amount of nitrogen to produce higher grain yield. All factors including climatic, varietal and management should be considered together in evaluating the nitrogen response of rice (De Datta and Malabuyoc, 1976). Similarly, the response of rice plant with added nitrogen is largely influenced by variety, soil fertility, environmental factors and management practices reported by (BRRI, 1988 and BRRI, 1989). An investigation at BRRI revealed that the yield increases with the increasing rate of applied nitrogen and this was fairly related with the increasing number of panicles per unit area (BRRI, 1986). Phongpan *et al.,* (1988) reported that the grain and straw yield as well as nitrogen uptake by rice increased significantly with increasing rates of urea application. Experimental results revealed that nitrogen content in grain and straw increases considerably due to nitrogenfertilization (BRRI, 1989 and BRRI, 1990). Another experiment showed that the application of 40 kg N/ha increased yield from 5.0 t/ha to 6.3 t/ha but further addition of nitrogen did not increase the yield (BRRI, 1988). Baba, (1956) reported that thousand grain weight has little relation to nitrogen supply. A high nitrogen supply is reported to decrease the thousand grain weight. Application of nitrogen increased gel consistency and decreased amylose content of rice kernel; however, had not significantly affected gelatinization temperature and grain protein content (Bahmaniar *et al.,* 2007). In general, milled rice translucency improved but Kett whiteness decreased with late nitrogen fertilizer application. Brown rice weight was not affected by late nitrogen application. In most cases, there was a significant positive correlation between head rice yield, milled rice protein and translucency (Perez *et al.,* 1996).

Potassium: Potassium is commonly present in all globoids reported by Wada and Lott, (1997). Application of potassium increased gel consistency and grain protein content but had not significantly affected gelatinization temperature and kernel amylose content (Bahmaniar *et al.,* 2007). At the standard protein intake, even with higher potassium levels in the brown rice diet, absorption rates of potassium was still significantly lower for the brown rice diet (Miyoshi *et al.,* 1987b). Siscar-Lee *et al.,* (1990) reported that in four pairs of rice differing in salt tolerance, grown in saline and normal soils condition. Potassium content was lower in three of the four pairs of rice of the saline crop. A shortage of potassium in body fluids may cause a potentially fatal condition known as hypokalemia, typically resulting from vomiting, diarrhea and increased diuresis (Slonim and Pollack, 2006). Deficiency symptoms include muscle weakness, paralytic ileus, ECG abnormalities, decreased reflex response and in severe cases respiratory paralysis, alkalosis and cardiac arrhythmia (Visveswaran, 2009).

Sodium: Sodium is an essential nutrient that regulates blood volume, blood pressure, osmotic equilibrium and p^Hbut becomes harmful for body at high level. In animals, sodium ions are necessary for heart activity and certain metabolic functions reported by (Pohl *et al*., 2013). At the standard protein intake, even with higher sodium levels in the brown rice diet, absorption rates of sodium was still significantly lower for the brown rice diet (Miyoshi *et al.*, 1987b). Siscar-Lee *et al.*, (1990) reported that in four pairs of rice differing in salt tolerance, grown in saline and normal soils condition. Sodium content was higher in brown rice produced in saline soil (70-180 ppm) than in normal soil (19-37 ppm).

Iron: Iron was found mostly in radical tissue globoids of rice reported by Wada and Lott, (1997). Rice is the cereal crop, which in general is not rich in iron stated by Welch and Graham, (2000). Iron is one of the most important micronutrients in the human diets. The deficiency of iron caused anemia affecting a healthy life development (Hoa and Lan, 2004). Severe anemia increases the risk of death for women in childbirth. Iron deficiency during childhood and adolescence impairs physical growth, mental development and learning ability. In adults, it reduces the ability to do physical labor. César *et al*., (2010) reported that values for brown rice had (10-11) ppm for iron. Iron content had 11.9 ppm in brown rice and 5.0 ppm in milled rice (Juliano, 2003). So, iron levels in milled rice are lower than these in brown rice but the decrease differs with variety. Iron was most abundant at 49.87 mg/kgin a core collection of Yunnan rice (Zeng *et al*., 2004). Fertilizer nitrogen, but not phosphorous and potassium, increases iron level in brown rice (Gregorio *et al*., 2002). Similarly, iron content in rice is influenced by nitrogen application and soil quality (Senadhira *et al*., 1998).

Zinc: Zinc was commonly found in globoids of the scutellar epithelium and radical of rice (Wada and Lott, 1997). In cereals, most of the zinc is found in the outer fiber-rich part of the kernel, thus the degree of refinement determines the total zinc content. César *et al*., (2010) reported that values for brown rice had (20-25) ppm for zinc. Zinc content in rice is influenced by nitrogen application and soil quality (Senadhira *et al*., 1998). Juliano, (2003) reported that zinc content had 27.2 ppm in brown rice and 16.5 ppm in milled rice. Cereals and grain based-products provide about 13% of the zinc in the food supply (Welsh and Marston, 1982). So, cereals may become increasingly important sources of zinc as people become more aware of the health benefits associated with increased intake of these foods (Anonymous, 1988). The association of crude protein is significant but positive with zinc content (Premila *et al.,* 2012). Zinc deficiency was first identified as a field problem in rice in 1966 (Nene, 1966). It is now widely recognized as one of the most widespread soil constraints in rice production, with as much as 50% of all lowland rice soils prone to zinc deficiency (Sillanpaa, 1990 as well as White and Zasoski, 1999).

2.5 Nutritional quality

Carbohydrate content: Carbohydrates comefrom a wide source of foods including cereals (rice, wheat, maize, oat etc), fruits, vegetables and dairy products. They are classified as simple or complex carbohydrate based on the length of carbon molecules in the particular carbohydrate. Rice is considered as complex carbohydrate because it is primarily comprised of long-chain polymers. Not only carbohydrate is important for human diet of healthy living but also it is essential forthe body’s main energy source. So, carbohydrate provides fuel to do everything. In fact, it is so essential that it provides the lion’s share of the calories in a balanced diet. Carbohydrate content was high in all rice varieties (>70%) and hence can be considered to be a good source of carbohydrate (Rachel *et al*., 2013). Among the tested rice samples carbohydrate content varied from (73.1-78.0)% in brown and (77.1-81.1)% in milled rice of traditional varieties (Siddiquee, 2010). Although the polishing of rice increased the content of carbohydrate in both traditional and HYV rice but there was no significant difference in carbohydrate content of traditional and HYV rice (Siddiquee, 2010).

Fat content: Rice is not a significant source of dietary fat. The ranges of fat content of different rice genotypes had (0.30-0.55)%, (0.36-0.69)%, (0.89-1.27)%and (1.1-1.9)% reported by Juliano *et al*., (1964); Chakraborthy *et al*., (1972); Singh *et al*., (1999)and Siddiquee, (2010).Furthermore, the ranges of fat content of (0.15-0.67)% for parboiled and (0.19-0.57)% for unparboiled rice reported by Zakir and Biswas, (2009).The low fat content (0.07%) was recorded in black rice variety (Rachel *et al*., 2013). Interestingly, it will be noted that practically the entire amount of the grain lipid is present on the grain surface after about (4-5)% degree of milling. Milling of rice removes the outer layer of the grain where most of the fats are concentrated (Frei and Becker, 2003). Crude oil contents in milled rice decreased from 0.98% to 0.13%, when the polishing time increased from 5 seconds to 40 seconds (Muhammad *et al*., 2002). *Waxy* brown and milled rice had higher crude oil content than non-*Waxy* Japanese brown rice and milled rice (Taira and Hiraiwa, 1982). Furthermore, indica rice had less oil content in brown rice than japonica rice (Taira and Chang, 1986). Variability in crude oil content of brown rice due to variety and mean ambient temperature during ripening has been reported. Both season and variety significantly affected crude oil content of brown rice (Villareal and Juliano, 1989).

Ash content: Ash content, which in turn indicated the mineral composition of the rice grain, was an important component in determining its quality (Sujatha *et al*., 2004). The amount of ash present in a food sample played an important role while determining the levels of essential minerals (Bhat and Sridhar, 2008). The average values of ash content had 1.18%, 0.55%, 1.75% and 0.6% reported by Doesthale *et al*., (1979); Heinemann *et al*., (2005); Kouakou *et al.,* (2008) and Siddiquee, (2010). The ash content was high 0.90% in black rice but low 0.39% in white rice (Rachel *et al*., 2013). The results of ash content among parboiled group had the highest amount of ash 0.64% in BRRI dhan29 but the lowest 0.41% in BR11 (Zakir and Biswas, 2009). Parboiled rice and un-parboiled rice presented similar ash contents (P>0.05), indicating that the parboiling did not cause a significant loss of minerals, had been observed previously by Doesthale *et al.,* (1979). The varietal variation in ash content may be due to the degree of milling/polishing which influenced by varietal effect.Veena *et al*., (1999) observed similar phenomenon in milled rice. Ash content of polished samples decreased from 1.2% to 0.64% at 11.35% degree of polished rice (Veena *et al*., 1999).

Crude fiber content: Traditionally dietary fiber has been defined as the non-starch polysaccharide constituent of plant cell walls. It is now understood that dietary fiber is not a homogenous substance but instead comprises a group of chemically diverse compounds. Dietary fiber, especially which found in whole grains, is resistant to human digestive enzymes in the intestinal tract. So, increase in fiber content in rice may improve the human health by lowering the plasma cholesterol level revealed by Abdul and Yu, (2000). Dietary fiber results in reduction of the risk of bowel disorders and fights constipation reported by Champe and Harvey, (1994).

For crude fiber, the values were in the range of 7.07% to 8.47% among the analyzed black rice samples (Rachel *et al*., 2013).The crude fiber content of various rice varieties ranged between 0.34% and 0.88% for un-parboiled group (Zakir and Biswas, 2009). Highest amount of crude fiber was found in the black rice. So, black rice is known to be a good source of fiber. Therefore, there was no significant difference recorded for crude fiber content between brown and black rice varieties (Rachel *et al*., 2013). Dietary fiber has no effect on mineral utilization concluded by Gordon *et al*., (1994). But dietary fiber reached food may reduce in absorption of minerals and other nutrient density. It is estimated that half cup of cooked brown rice provides 1.8 g dietary fiber which is higher than that in cooked white rice 0.3 g of dietary fiber (Mitra *et al*., 2007). Experts recommend we consume at least 25 g of fiber every day to decrease risk of chronic diseases. The current dietary recommendation is of 20-30 g of fiber per day as mentioned by Yue and Waring, (1998).

Moisture content: Moisture played a significant role in determining the shelf-life (Webb, 1985). At the time of harvesting, rice has a relatively high moisture content which is then lowered to suitable storage moisture levels by drying. Paddy rice, after harvesting, contained up to 13% of moisture which reduce to significant level after removing the husk (Ibukun, 2008). Moisture content of rice often varied from 7% to 11% in rice grain (Stanely, 1987 and Awan, 1996). The average moisture contents of commercial rice from Brazil varying between 9.4% and 13.5%, which is the safe storage of processed rice revealed by Heinemann *et al*., (2005).

Grains with high moisture contents were difficult to store safely because these were more vulnerable to attack by pests and diseases as well as hydrolytic changes (Gooding and Davies, 1997). High moisture directly reduces the grade of rice; if the grain molds or spoils, the grade is lowered even more. To avoid insect infestation and micro-organisms development, 12% moisture contents is recommended during long term storage. However, the moisture content itself also has some effect on milling. Pominski *et al*., (1961) noted that the laboratory milling yield (using McGill equipment) of raw rice was affected by the moisture content of paddy at the time of milling. The low moisture level may be due to the initial moisture content (<14%) of the paddy of the various rice varieties prior to milling revealed by Zakir and Biswas, (2009). Relatively high grain moisture (>14%) promoted grain breakage, including even of some sound grain in favorable circumstances (Kunze *et al*., 2004).

Protein content: Cereals are the major source of dietary protein for a large population. The intake of rice protein exceeds other cereal protein such as wheat protein and maize protein.

So, rice is the main source of protein for most of the rice consuming people reported by Mitra and Das, (1971) as well as Gomez, (1979). It supplies a large proportion of the protein intake for many millions of people reported by Pereira *et al.*, (1981**)** and supplies 55% of the total protein consumed in Bangladesh reported by Bhuiyan *et al*., (2002).

Growing group of scientists who feel that protein plays a substantial role in varietal difference of rice. The range of protein content had (5-17)% in brown rice, (4.3-8.2)% in rice, (7.38-8.13)% in rice, (6.3-9.1)% in rice and (5.0-9.5)% in milled rice reported by Juliano, (1968); Gomez, (1979); Awan, (1996); Riza *et al.,* (2004) and Chandel *et al.,* (2005). Milled rice contains average protein content of 8.0% and 6.6% reported by McCall *et al.,* (1953) as well as Bandemer and Evans, (1963). On the other hand, brown rice from upland rice crops exhibited the higher protein content than that of flooded rice (Taira, 1970); high ambient temperature and high water temperature increased the protein content (Honjo, 1971); the variation in protein content is due to management and cultural practices, environmental and weather conditions (De Datta *et al*., 1972);grain-to-grain variation occurred in protein content even in the same panicle (Juliano *et al.,* 1972b) as well as soil nitrogen, solar radiation, degree of plant maturation, application of fertilizer and shorter maturation periods influenced protein content (Juliano and Bechtel, 1985).

Spanish scientists in IATA were the pioneers in propounding the importance of rice protein. They were of the firm opinion that protein had a significant role in rice quality. Moreover, rice protein is hypoallergenic and rich in lysine. As a result, rice protein is widely used in infant foods and the formulation of restricted recipes for children with food allergies (Burks and Helm, 1994). Greater protein content in the outer layers of rice rendered it less sticky after cooking showed by Primo *et al*., (1962). High protein rice requires longer cooking time and greater moisture content compared to low protein rice found by Yadav and Jindal, (2007). Grain yield and protein content of rice are generally correlated negatively reported by Ghosh *et al*., (1971)as well as Govindaswami and Ghosh, (1974); therefore, improving both without breaking the existing correlation is not possible.

Milling effect on protein: Brown rice with higher protein content was more resistant to abrasive milling than brown rice with lower protein content in the same cultivar found by Cagampang *et al*., (1966). Protein content in milled rice decreased from 10% to 7.9%, when the polishing time increased from 5 seconds to 40 seconds (Muhammad *et al*., 2002). The range of protein loss of 2 rice varieties was (7.26-7.68)% and (6.19-6.65)% during milling for various duration (20, 30, 40 and 50) sec reported by Saleh and Meullenet, (2013). The removal of protein-containing layers of the rice grain (aleurone and subaleurone) appeared to be the same extent for both traditional and HYV milled rice (Siddiquee, 2010).

Cooking effect on protein: Cooking of rice varieties significantly resulted in nutrients depletion, especially in protein. These losses in nutrients may be due to protein denaturation, anti-nutritive factors, extraction and leaching effects of water (Adeyemi *et al*., 1986; Bhattacharya and Ali, 1986; Perez *et al*., 1987 as well as Adeyeye and Ajewole, 1992). Protein loss during cooking was 0.5% reported by Juliano, (1993). Raw and cooked rice protein content of Ofada and Aroso rice had (7.30-4.19)% and (6.95-3.50)% respectively. So, protein depletion occurs in both indigenous (Ofada) and foreign (Aroso) rice varieties during cooking reported by Osaretin *et al*., (2007).

Fractionation ofprotein: Rice protein in the endosperm tightly associates on the surface of starch granules (Tanaka, 1980). Osborne, (1907) reported that the outer tissues (aleurone layers and germ) of the rice grain are rich in albumin and globulin, whereas endosperm of milled rice is richest in glutelin, i.e. glutelin is the most abundant storage protein (65%) in rice endosperm. Prolamin is a minor fraction in all protein fractions of the rice grain. Houston *et al*., (1968) studied in considerable detail the radial distribution of protein in the rice grain. They found the similar result; the outer layers were comparatively richer in albumin and globulin than the core. Furthermore, Villareal and Juliano, (1978) suggested that glutelin is mainly found in the endosperm of rice grain.

Cagampang *et al*., (1966) fractionated three varieties of rice. In all the three cases he found glutelin to be the dominant fraction in whole as well as in the milled grain. Albumin and globulin fractions formed bulk of the bran and polish proteins. Prolamin was evenly distributed in all three fractions: bran, polish and milled rice. The increase in brown rice protein content due to environment results mainly an increase in glutelin, although prolamin also increases. So, Cagampang *et al*., (1966) concluded that major differences in protein could be explained on the basis of differences in the glutelin content.Osborne (1907) reported that the rice grain has about 10% albumin, 5% globulin, 20% prolamin and 65% glutelin. The former values were 10% albumin, 5% globulin, 5% prolamin and 80% glutelin. Using sequential protein extraction, the mean ratio for 33 samples was found to be 7% albumin plus globulin, 9% prolamin and 84% glutelin (Huebner *et al*., 1990).

Amino acid composition: In nutritional evaluation of the protein in rice, the protein content and the amino acid composition of polished rice were important (Matsuo *et al.*, 1995).Amino acid composition showed slightly higher lysine content for brown rice protein than for milled rice protein (USDA, 1998). Lysine was the first limiting amino acid of rice protein (Choudhury *et al.,* 1999). Threonine was another limiting amino acid of rice protein. Lysine and threonine were considered to be the limiting amino acids in rice protein (Watanabe, 1959; Ingaki *et al*., 1963 and Chen *et al*., 1967). According to Zainuddin *et al.,* (1990), glutamic acid, glycine and methionine were the major amino acids of rice whereas Prakash and Ramanatham, (1995) reported threonine and isoleucine were the minor amino acids of rice. Siddiquee, (2010) reported that the range of amino acid composition such as arginine, lysine, alanine, threonine, glycine, valine, serine, isoleucine, leucine, methionine, glutamate, aspartate and tyrosine had (7.5-8.0)%, (3.0-4.0)%, (7.2-8.6)%, (3.1-3.5)%, (6.2-7.9)%, (5.3-6.0)%, (5.2-5.9)%, (4.1-4.5)%, (7.7-8.2)%, (4.0-5.5)%, (4.5-4.9)%, (2.7-4.1)% and (2.4-3.3)% respectively. Amino acids were varied significantly ($p< 0.05$) among the tested varieties of rice (Zubair, 2011).

Protein digestibility: Rice protein is highly digestible. In vitro protein digestibility of japonica rice was higher than that of indica rice (Wenwei *et al*., 2010). Tanaka (unpublished data) observed a higher in vitro pepsin digestibility of protein for raw rice in three japonica rice (78-80)% than in three indica rice (Boisen *et al*., 2001). The protein digestion of rice flake ranged from 38% to 78% among different samples (Madhu *et al*., 2007). In vitro protein digestibility was increased appreciably due to reduction in anti-nutrient contents (phytic acid and polyphenols) after 48hr germination (Shalini and Sudesh, 2002). Cooking may destroy the anti-nutritional factors present in rice and render rice protein more digestible. Furthermore, protein from rice also has fiber suitable for digestion and reducing cholesterol revealed by Tobiason, (2006).

Starch digestibility: Starch is a major source of energy to the world′s population. Starchy plants, extensively grown which used for human consumption belong to tubers, pulses/legumes and cereals (Würsch, 1989). Starch is the major component of rice constituting about 90% of its dry matter reported by Patindol *et al.,* (2009). The highest starch digestibility had 86.56% of BRRI Dhan40 and lowest starch digestibility had 74.13% of BRRIdhan26 in the parboiled rice cultivars having more than (>70.4%) starch digestibility for all tested varieties (Zakir and Biswas, 2009). Amylose content alone is not a good predictor of starch-digestion rate reported by Panlasigui *et al.,* (1991).Furthermore, rice varieties with similar high amylose content can differ in physicochemical (gelatinization) properties and this, in turn, can influence starch digestibility also reported by Panlasigui *et al*., (1991). Similarly, the marked improvement of starch digestibility in rice may be attributed to the gelatinization of starch granules revealed by Juliano, (1984). In vitro starch digestibility was increased appreciably due to reduction in anti-nutrient contents (phytic acid and polyphenols) after 48hr germination (Shalini and Sudesh, 2002).

2.6 Genetic diversity of *Waxy* gene

Amylose content: Starch is the most common carbohydrate in the human diet. It consists of amylose and amylopectine. Amylose content of rice is considered as the main parameter of cooking and eating quality (Juliano, 1972).Similarly, amylose content can play a significant role in determining the overall cooking and eating properties of a rice variety (Adu-Kwarteng *et al*., 2003 and Asghar *et al*., 2012). Furthermore, apparent amylose content (AAC) is the key determinant of the different rice (*Oryza sativa*) cooking, sensory and processing properties (Bergman *et al*., 2004). The higher the amylose content, the more firm, flaky, springy and chewy the cooked rice is when eaten. Cultivars with low amylose are tender, glossy and cohesive after cooking (Juliano, 1992). Low amylose content of the seed is desirable for certain special occasions (Isshiki *et al*., 1998). Most of the Bangladeshi people prefer high amylose content rice cultivars. Rice varieties may be classified as glutinous (*Waxy*), low, intermediate and high amylose content with the range of (0-2)%, <20%, (20-25)% and >25%, respectively (Juliano, 1971). Glutinous rice lacks the starch amylose, which constitutes up to 30% of the total starch in the non-glutinous rice endosperm (Oka, 1988 and Morishima *et al*., 1992). The range of amylose content had (26.0-27.0)% reported by (Panlasigui *et al.,* 1991). Amylose content in long grain rice varieties can range from 23.0% to 26.0% reported from Rice Quality Workshop, (2003). Devi *et al.,* (2008a) reported some indigenous cultivars had the range of amylose content from 2.27% to 24.5% with rice kernel length roughly varies from 5.0 mm to 7.5 mm. Zakir and Biswas, (2009) also reported that amylose content of the milled rice collected from different cultivars varied from 21.3% to 29.1% with length of this milled rice varied from 3.93 mm to 6.70 mm. Hasiba *et al.,* (2006) revealed that the range of amylose content of rice starch varied from 22.8% to 27.4% in modern and 10.2% to 27.6% in local rice varieties with length of milled rice varied from 5.2 mm to 6.4 mm in tested modern varieties and the length of milled rice varied from 5.4 mm to 6.1 mm in tested local cultivars.

Higher environmental temperature has been shown to decrease amylose content in the endosperm starch of non *Waxy* rice plant (Asaoka *et al.*, 1985). Hirano and Sano, (1998) as well as Larkin *et al.,* (1999) also reported that the temperature during grain-filling influences the amylose content in rice endosperm starch. Some rice varieties accumulate more amylose when grain-filling proceeds under cooler temperature. Many reports suggested that the increase in the amylose content at cool temperature might be regulated by the *Waxy* locus. Biselli *et al.*, (2014) reported that haplotypes at the *Waxy* locus were also associated to grain length and length/width (L/W) ratio. The *Waxy* gene in rice is located on chromosome 6 and has been shown to play a key role in amylose synthesis (Smith *et al*., 1997). Similarly, Preiss, (1991) as well as Nelson and Pan, (1995) reported that the rice *Waxy* locus encodes granule-bound starch synthase (GBSS), a key enzyme in amylose synthesis of plants. The level of grain amylose is directly associated to the amount of GBSS in the endosperm (Mikami *et al.,* 2008).

Microsatellite and cleaved amplified polymorphic sequence markers: Molecular marker (*Waxy* F-R) might be useful in marker-assisted breeding to improve rice genotypes with amylose content (Nguyen *et al.,* 2004). The microsatellite marker (RM190F-R) and RM190F-GBSSW2R with restriction enzyme (*AccI*) were closely linked to the *Waxy* gene reported by many reports.The sequence of microsatellite RM190F-R is as same as microsatellite 484-485.A polymorphic microsatellite marker (RM190) having a (CT)n repeat was identified in the 5′ non-translated region of the rice *Waxy* gene which was located closely linked to the rice *Waxy* gene (Bligh *et al*., 1995). Ayres *et al.,* (1997) reported eight (CT)n microsatellite alleles with n = 8, 11, 14, 16, 17, 18, 19, and 20. Bergman *et al.,* (2001) also reported an additional allele, $(CT)_{10}$. This microsatellite explained 82.9% variation was found in apparent amylose content of 89 non-glutinous USA rice cultivars and 101 progeny of a cross between low and intermediate amylose breeding lines (Ayres *et al.,* 1997).

The *Wxa* allele contains an efficient intron 1 splice site (AGGTATA) for normal gene expression and plants expressing this allele contain intermediate to high amylose content. The *Wxb* allele commonly carries a single nucleotide variation at the first intron splice site [AG(G/T)TATA]. The G-to-T base substitution reduces the efficiency of the first intron splicing and subsequently depresses GBSS expression as reported by Wang *et al*., (1995). Among 190 rice cultivars an intronic single nucleotide polymorphism discriminated low apparent amylose content type cultivars (AG<u>T</u>TATA sequence) from intermediate and high apparent amylose content type cultivars (AG<u>G</u>TATA sequence) (Ayres *et al.,* 1997). Another study identified 56.1% of the variation in apparent amylose content by 484/W2R-*AccI*. Furthermore, 72.4% of the variation in apparent amylose content could be explained with both RM190 and 484-W2R/*AccI* (Wan *et al*., 2007). Single nucleotide polymorphism (SNP) was largely used to discriminate between high (G allele) and low (T allele) amylose containing rice cultivars. But, some Bangladeshi rice cultivars had exception, 3 cultivars had (G allele) with low amylose content (Rokeya, unpublished data).

2.7 Hybridization

The collection, documentation and characterization of germplasm is important for utilizing the appropriate trait based donors in breeding program and essential for protecting the unique rice varieties (Rita *et al*., 2008). Rice breeders need to pay more attention to selecting plant types that have a high degree of uniformity of grain characteristics on the panicle and to those traits (such as greater grain size and weight) that have a positive impact on yield and milling quality were reported by Jongkaewwattana and Geng, (2001). The basic study on genotypes for yield contributing characters of traditional aromatic varieties and other quality traits would help in making precise breeding strategies (Sarawgi and Rita, 2006). Therefore, rice breeders should consider the better quality of new rice varieties in addition to higher yield potential (Adnyana *et al*., 2008).

Bashar, (2002) reported that the cross 'BR4828×IR8' (F_1) exhibited the highest thousand grain weight (28.15 g). Singh, (1980) conducted an experiment on association of grain yield and its components in F_1 populations of rice. Correlation analysis of data from segregating and non-segregating populations from a 6×6 diallele, excluding reciprocals, revealed that grain yield per plant was positively correlated with number of fertile tillers, grain weight and number of fertile grains per panicle in both F_1 generations. Measurement of five yield characters in 33 F_1 hybrids of rice showed that eight hybrids were significantly higher than the better parent for yield and seven were better for number of spikelets per panicle. Biswas *et al*., (2000) studied 30 advanced breeding lines of rice and found higher values of genotypic and phenotypic variance on plant height, filled grains per panicle and thousand grain weight. But number of panicles per hill and panicle length showed minimum amount of variation in both genotypic and phenotypic level. Heritability in broad sense was the highest for thousand grain weight followed by panicle length. But filled grains per panicle, plant height, number of panicle per hill and yield per plant showed moderate heritability. Thousand grain weight, panicle length and filled grains per panicle showed moderate genotypic coefficient of variation together with high genetic advance in percentage of mean.

High genotypic and phenotype coefficient variations were recorded by Iftekharuddaula *et al*., (2001) for number of filled grains per panicle and spikelet sterility while evaluating 24 modern rice varieties. But it was moderate for plant height, number of panicles per hill, thousand grain weight and grain yield per hill. They also reported moderate value of heritability for number of panicle per hill. Plant height, number of filled grains per panicle and thousand grain weight showed high heritability with moderate genetic advance in percent of mean.

Nutritional genomics is a new term referring to a combination of biochemistry, genetics, molecular biology and genome-based technologies to investigate and manipulate plant compounds with nutritional value (Tian and DellaPenna, 2001). Somasekharan and Khaleel, (2013) demonstrated that the total protein in the F_1 soybean plants of irradiated seeds increased with the increase in the radiation dosage and was found to be higher than the seeds of non-irradiated F_1 soybean plant. Kereši *et al*., (2008) reported that obtained results suggested that soybean genotypes with favorable traits, such as variety Linda, line 1511, and F_1 hybrids (Linda x LN92-7369) and (Balkan x BL-8), could be used in breeding drought more tolerant genotypes with higher nitrogen-fixing capacity and high protein content. Qi *et al*., (1990) studied heterosis of physiological characters in F_1 hybrids between indica and japonica crosses of rice. Physiological characters of F_1 from 9 combinations and quality characters of F_1 from 7 cross combinations of 5 indica rice cultivars and 6 japonica ones were studied. Heterosis values for amylose content and gelatinization were statistically significant. The endosperm of F_1 seeds was translucent when lines with intermediate or high amylose content were used as pollen parents reported by Kumar and Khusu (1986). The progenies were tested for amylose content and classified as low, intermediate and high. The amylose content varied among the progenies. The combinations of Q76 and MR84 had high amylose content while Q76 and MRQ74 had low. Combinations of intermediate and high amylose or high and low amylose or intermediate and low amylose content resulted into the F_1 progenies with high or intermediate or low amylose content reported by Rafii *et al*., (2014). Crosses derived from awned rice parents produced F_1 plants with awns, indicating that awn production is a dominant trait (Adair *et al*., 1973).

Chapter 3

MATERIALS AND METHODS

3.1Sample collection

A set of 129rice germplasams used in this study werecomposed of 109 local cultivars and 20 BRRI developed HYVs as standard check (Table-3.1a,Table-3.1b and Table-3.1c). Three groups of these varieties (long, medium and short grain) were selected for this research.The local cultivars and modern varieties of rice (5g) were collected for field experiment from the BRRI gene bank at Genetic Resource and Seed Division of Bangladesh Rice Research Institute,Gazipur.The field experiment was conducted in the farm of Bangladesh Rice Research Institute(BRRI),Gazipur in T.Aman season,2009.

Table-3.1a: List of long grain local rice cultivars and HYVs

Sl. No.	Cultivars	Specification	Source
1	Athabinni	T.Aman (BRRI Acc.# 4483)	Tangail
2	Bhorochalam	T.Aman(BRRI Acc.#392)	Rajshahi
3	Binni-1	T.Aman (BRRI Acc.# 4477)	Sherpur
4	Binni-2	T.Aman	
5	Boradudhkalam	T.Aman(BRRI Acc.# 280)	Rangpur
6	Cylindrical Tapi-629	T.Aman(BRRI Acc.#3016)	
7	Depa	T.Aman(BRRI Acc.#326)	Rangpur
8	Dudhkalam	T.Aman(BRRI Acc.# 279)	Rangpur
9	Dudsar Tapal-146	T.Aman(BRRI Acc.#2569)	
10	Gohatibinni	T.Aman (BRRI Acc.# 4485)	Sherpur
11	Harilaxmi	T.Aman(BRRI Acc.#3271)	Dhaka
12	Hatisail	T.Aman (BRRI Acc.# 31)	Dhaka
13	Jingasail-1	T.Aman(BRRI Acc.#290)	Rangpur
14	Joalbagh	T.Aman(BRRI Acc.#907)	Sylhet
15	Jol	T.Aman(BRRI Acc.#3252)	Dhaka
16	Kalabinni-1	T.Aman (BRRI Acc.# 4118)	Cox’ Bazar
17	Kalimanik	T.Aman(BRRI Acc.#4118)	Barisal
18	Kanaibansi	T.Aman(BRRI Acc.#297)	Rangpur
19	Karailadhan	T.Aman(BRRI Acc.#3310)	Dhaka

Sl. No.	Cultivars	Specification	Source
20	Kharmao	T.Aman(BRRI Acc.#295)	Rangpur
21	Khorma	T.Aman(BRRI Acc.# 235)	Mymensingh
22	Lathamona	T.Aman(BRRI Acc.# 3884)	Barisal
23	Molladigha	T.Aman(BRRI Acc.#2404)	Dhaka
24	Neda	T.Aman (BRRI Acc.# 4920)	Pakistan
25	Pakhisail	T.Aman (BRRI Acc.# 4157)	Kishoregonj
26	Patnai-231	T.Aman(BRRI Acc.#52)	Barisal
27	Redpiebald-219	T.Aman(BRRI Acc.#2639)	
28	Sadajira Tapl-321	T.Aman(BRRI Acc.#2732)	
29	Shata	T.Aman (BRRI Acc.# 4982)	Pabna
30	Shithabhog	T.Aman (BRRI Acc.# 3894)	Barisal
31	Tk deep straw Tapl-773	T.Aman(BRRI Acc.#3156)	
32	T.R.Aman	T.Aman(BRRI Acc.#1228)	Faridpur
33	BR23	T.Aman	BRRI,Gazipur
34	BRRI dhan30	T.Aman	BRRI,Gazipur
35	BRRI dhan39	T.Aman	BRRI,Gazipur
36	BRRI dhan41	T.Aman	BRRI,Gazipur

Table-3.1b: List of mediumgrain local rice cultivars and HYVs

Sl. No.	Cultivars	Specification	Source
1	Bariksail	T.Aman (BRRI Acc.# 896)	Sylhet
2	Bolonga	T.Aman (BRRI Acc.# 4140)	Natore
3	Boylam	T.Aman (BRRI Acc.#)	Barisal
4	Chamara	T.Aman (BRRI Acc.# 2006)	Mymensingh
5	Changai	T.Aman (BRRI Acc.# 6704)	Satkhira
6	Dadkhani	T.Aman (BRRI Acc.# 6721)	Rajshahi
7	Dholagachha	T.Aman (BRRI Acc.# 3285)	Noakhali
8	Ganjia	T.Aman (BRRI Acc.# 284)	Rangpur
9	Gobcha	T.Aman (BRRI Acc.# 4148)	Jessore
10	Gojalgoria	T.Aman (BRRI Acc.# 282)	Rangpur
11	Hashfol	T.Aman (BRRI Acc.# 113)	Dhaka
12	Hathazi	T.Aman (BRRI Acc.# 4116)	Chittagong
13	Hijli	T.Aman (BRRI Acc.# 3216)	Dhaka
14	Jhingasail-2	T.Aman (BRRI Acc.# 452)	Rajshahi
15	Jhoshua	T.Aman (BRRI Acc.# 286)	Rangpur
16	Joyna	T.Aman (BRRI Acc.# 6387)	Barisal
17	Kajalsail	T.Aman (BRRI Acc.# 3218)	Dhaka
18	Kalabinni-2	T.Aman (BRRI Acc.# 236)	Mymensingh
19	Kalisayta	T.Aman (BRRI Acc.#)	
20	Kanaklata	T.Aman (BRRI Acc.#)	
21	Kataribhog-1	T.Aman (BRRI Acc.#)	
22	Kataribhog-2	T.Aman (BRRI Acc.#)	
23	Kataribhog-232	T.Aman (BRRI Acc.# 232)	Mymensingh
24	Kumragoir	T.Aman (BRRI Acc.#)	
25	Lalbinni	T.Aman (BRRI Acc.# 209)	Mymensingh
26	Lalmota	T.Aman (BRRI Acc.# 1039)	Bagerhat
27	Lalsoru	T.Aman (BRRI Acc.# 281)	Rangpur
28	Lohasail	T.Aman (BRRI Acc.#)	
29	Ledabinni	T.Aman (BRRI Acc.# 4478)	Sherpur
30	Magoibalam	T.Aman (BRRI Acc.# 3222)	Tangail
31	Maloti	T.Aman (BRRI Acc.# 894)	Sylhet
32	Malsira	T.Aman (BRRI Acc.# 309)	Rangpur
33	Motichak	T.Aman (BRRI Acc.# 4735)	Khulna
34	Najirsail	T.Aman (BRRI Acc.# 1229)	Faeidpur
35	Nakchi	T.Aman (BRRI Acc.#)	
36	Nizersail	T.Aman (BRRI Acc.# 1229)	Faridpur
37	Nunia	T.Aman (BRRI Acc.# 233)	Mymensingh
38	Paharisail	T.Aman (BRRI Acc.# 293)	Rangpur
39	Pakibiroin	T.Aman (BRRI Acc.# 3284)	Noakhali
40	Poushmoricha	T.Aman (BRRI Acc.# 3286)	Noakhali
41	Putidepa	T.Aman (BRRI Acc.# 300)	Rangpur
42	Rajamora	T.Aman (BRRI Acc.# 1279)	Faridpur
43	Rangabinni	T.Aman (BRRI Acc.#)	

Sl. No.	Cultivars	Specification	Source
44	Tilkapur	T.Aman (BRRI Acc.# 3213)	Gazipur
45	Tilokkajal	T.Aman (BRRI Acc.# 1036)	Khulna
46	Sadamota	T.Aman (BRRI Acc.# 5953)	Bakerganj
47	Shamrose	T.Aman (BRRI Acc.# 221)	Mymensingh
48	Somondori	T.Aman (BRRI Acc.# 390)	Rajshahi
49	BR4	T.Aman	BRRI,Gazipur
50	BR10	T.Aman	BRRI,Gazipur
51	BR11	T.Aman	BRRI,Gazipur
52	BR22	T.Aman	BRRI,Gazipur
53	BR25	T.Aman	BRRI,Gazipur
54	BRRI dhan31	T.Aman	BRRI,Gazipur
55	BRRI dhan32	T.Aman	BRRI,Gazipur
56	BRRI dhan33	T.Aman	BRRI,Gazipur
57	BRRI dhan37	T.Aman	BRRI,Gazipur
58	BRRI dhan38	T.Aman	BRRI,Gazipur
59	BRRI dhan40	T.Aman	BRRI,Gazipur
60	BRRI dhan44	T.Aman	BRRI,Gazipur
61	BRRI dhan46	T.Aman	BRRI,Gazipur
62	BRRI dhan49	T.Aman	BRRI,Gazipur

Table-3.1c: List of shortgrain local rice cultivars and HYVs

Sl. No.	Cultivars	Specification	Source
1	Baoijhaki	T.Aman (BRRI Acc.# 4826)	Dinajpur
2	Betudhan	T.Aman (BRRI Acc.# 294)	Rangpur
3	Binniphul	T.Aman (BRRI Acc.# 424)	Rajshahi
4	Chinigura	T.Aman (BRRI Acc.# 4867)	Mymensingh
5	Chinisagor	T.Aman (BRRI Acc.# 245)	Mymensingh
6	Chunikanai	T.Aman (BRRI Acc.# 2012)	Khulna
7	Dudsail	T.Aman (BRRI Acc.# 4840)	Satkhira
8	Gurdoi	T.Aman (BRRI Acc.# 3188)	Gazipur
9	Jabsira	T.Aman (BRRI Acc.# 331)	Rangpur
10	Jirakatari-1	T.Aman (BRRI Acc.# 5045)	Dinajpur
11	Jirakatari-2	T.Aman (BRRI Acc.#)	
12	Kalasaru	T.Aman (BRRI Acc.# 4129)	Dinajpur
13	Kalijira	T.Aman (BRRI Acc.# 4820)	
14	Khasha	T.Aman (BRRI Acc.# 682)	Comilla
15	Lalsaru	T.Aman (BRRI Acc.# 4135)	Dinajpur
16	Laxmikajol	T.Aman (BRRI Acc.# 4161)	Satkhira
17	Malagrosa	T.Aman (BRRI Acc.#)	
18	Michisail	T.Aman (BRRI Acc.# 304)	Rangpur
19	Minki	T.Aman (BRRI Acc.# 4156)	Khulna
20	Murchmut	T.Aman (BRRI Acc.# 2014)	Khulna
21	Nariabochi	T.Aman (BRRI Acc.# 275)	Rangpur
22	Nurior	T.Aman (BRRI Acc.# 2416)	Dhaka
23	Pajam	T.Aman (BRRI Acc.# 4984)	Pabna
24	Rahikhama	T.Aman (BRRI Acc.# 2378)	Dhaka
25	Sorukamina	T.Aman (BRRI Acc.# 2015)	Khulna
26	Surjyamukhisangla	T.Aman (BRRI Acc.#)	
27	Topaboro	T.Aman (BRRI Acc.# 5041)	Pabna
28	Tulsimala	T.Aman (BRRI Acc.# 754)	Chittagong
29	Uknimadhu	T.Aman (BRRI Acc.# 298)	Rangpur
30	BR5	T.Aman	BRRI,Gazipur
31	BRRI dhan34	T.Aman	BRRI,Gazipur

3.2Germinationrate of the cultivars

It was a mini experiment which was conducted in the laboratory. A set of rice seed was used for germination test. For the determination of the dormancy period, germination test was started forrice seeds with an interval of three days and continued up to the attainment of >76% germination. A germinator was used for this purpose and the temperature was maintained at (31-36)^{0}C in it. Twenty five seeds were used per variety in three replications for germination to obtain required number of plants for data collection.

3.3Seedling rising

A land was ploughed, well puddled and leveled for the seedbed on 1st July 2009. Dry seeds of each variety were soaked on 30th June 2009 and sown on 2nd July 2009. The channel was used for irrigation and drainage. A foliar spray was done to protect the seedlings against insect pests.

3.4Field management

The land was ploughed by power tiller and leveled by laddering to make well puddled situation. A fertilizer rate of 60-40-10kg/ha of P-K-S in the form of triple super phosphate, muriateof potash and gypsumrespectively was applied as basal dose at final land preparation due to yield potential and requirement of nutrient elements.Nitrogen was 1st top-dressed as urea (35kg/ha)on 18th August 2009 and 2nd top-dressed (35kg/ha) on 15th September 2009 in two splits to the contrary of a common dose (70 kg/ha). The amount of urea and time of application were determined with the help of a leaf color chart (Ladha *et al.*, 1998).

The experiment was laid out in randomize complete block design (RCBD) with three replications. The dimension of an individual plot was 5.2 m × 5.2 m having plot to plot and block to block distance of 0.5 m and 1.0 m respectively. Thirty days old seedlings were transplanted on the (2nd August 2009 - 4th August 2009) at the rate of two seedlings per hill with the spacing of 20 cm × 20cm. A bundle of seedlings was kept at the side of each plot for gap filling and was done at seven days of transplanting to replace the dead ones. Hand weeding was done to keep the crop free from weed infestation throughout the crop growth phases. The field was irrigated properly and 5-10 cm water depths were maintained up to heading. A good drainage system was also maintained specially flowering. The excess water was drained out leaving the soil only at saturated condition. Sumithion 50 cc, Furadan 5g and Nanirate were applied for controlling gollmig, stemborar and rat.

3.5 Agronomic characters

3.5.1 Grain yield

Plants were harvested at crop maturity. All the plants of 5.2 m^2sample were cut at base. After threshing and cleaning, the fresh weight of grains was recorded on electric balance.

3.5.2 Thousand grain weight

A random sample of 1000 well-developed, whole grains at 13% moisture content was weighed on an electric balance.

3.5.3 Number of tiller/hill

A sample of one (3) hill was used to count the number of tillers.

3.5.4 Number of panicle/hill

A sample of one (3) hill was used to count the number of panicles.

3.5.5 Panicle length

It is the distance between apex of the panicle (excluding awn) and top most nodes (neck node) of the culm. Average of 5(10) randomly selected main panicles was recorded in cm from each plot at maturity stage.

3.5.6Plant height

It is the distance from ground level to the tip of the tallest leaf (panicle) of a plant. Average of 5(10) randomly selected plants was recorded in cm from each plot at maturity stage.

3.5.7 Growth duration

The duration in days from the date of seed soaking to the time when more than 80% grains on the panicles are fully ripened.

3.5.8 Percent of filled grains

A sample of 3 random panicles (plants) was used to count the grains (from all the panicles).

3.6 Morphological and physical properties

3.6.1 Panicle threshability

The panicle werefirmly grasped and pulled the hand over the panicle and estimated the energy of shattered grains were recorded according to procedure of BRRI Germplasams description and evaluation form.

1=Difficult
5=Intermediate
9=Easy

3.6.2 Panicle type

Panicles are classified according to their mode of branching, angle of primary branches and spikelet density were recorded (IRRI, 1996).

1=Compact
5=Intermediate
9=Open

3.6.3 Awn status

Awn status in the spikelet was recorded according to procedure of BRRI germplasams description and evaluation form.

1=Absent
9=Present

3.6.4 Hull color

Color of lemma and pale was noted at maturity stage according to the list given below.

0=Straw
1=Gold or gold furrows on straw background
2 = Brown spots on straw
3=Brown furrows on straw
4=Brown
5= Reddish to light purple
6= Purple spots on straw
7=Purple furrows on straw
8=Purple
9= Black

3.6.5 Pericarp color

Pericarpcolor of decorticated grain was visually classified into following four categories.

1 = White
2 = Lightbrown
3 = Dark brown
4 = Red

3.6.6 Grain size and shape

Length and breadth of rough, brown and milled rice was measured in millimeter using slide calipers.

Based on length, size of milled rice was classified into 3 classes.

Size	**Length in mm**
Long (L)	>6.0
Medium (M)	5.0-6.0
Short (S)	<5.0

Based on length to breadth ratio, shapeof milled rice was again classified into 3 classes.

Shape	**Length/Breadth ratio**
Slender (S)	>3.0
Bold (B)	2.0-3.0
Round (R)	<2.0

3.6.7 Chalkiness

The degree of chalkiness was determined using milled rice upon visual observation. Based on the observation the chalkiness of the endosperm was classified into white belly, white center, opaque and translucent. When the chalkiness is present in the whole endosperm is called opaque but there is no chalkiness in the endosperm is called translucent. Furthermore, when the chalkiness is present either on the ventral side of rice grains is called white belly or in the center part of the rice grains is called white center.Amount of chalkiness, either on the dorsal side (white belly) or in the center (white center) of the endosperm influences the grain appearance of milled rice. An international standard scale was used for classifying endosperm chalkiness of milled rice (Khush *et al.*, 1979).

Scale	% of area with chalkiness
0	0% (none)
1	Less than10% (small)
5	(10-20)% (medium)
9	More than 20% (large)

3.6.8Appearance

Grain appearance was done by visual observation. Size and shape, uniformity, presence or absence ofendosperm opacity and level of chalkiness were collectively considered for the classification of excellent, very good, good and fair grain.

3.7 Milling and cooking properties

3.7.1 Milling properties

3.7.1.1 Milling of rice (Hull content, Milling outturnand Head rice recovery)

Rough rice was cleaned to remove leaves, rice stems and other foreign materials. After that, it was sun dried before milling. Duplicate 200 g rough rice was dehulled by Satake THU-35A sheller to brown rice. The resulting brown rice was milled in Satake TM-05,mill with #5330 abrasive disc at 1730 rpm to obtain approximately 10.0% by weight bran-polish removal for all samples (the partofbrown rice which includes pericarp, embryo,aleurone and sub-aleurone layer). The broken grains were separated manually. Milled rice yield and head rice recovery was expressed as percentage of rough rice and milled rice basis. Rice powder was prepared by grinding milled rice in Udy Cyclone Mill (Udy Corporation, USA) to pass through 60 meshes net.

Calculation

The percent of hull, brown rice, degree of milling, total milled riceand head rice werecalculated as follows:

$$\text{Hull (\%)} = \frac{\text{weight of hull}}{\text{weight of rough rice}} \times 100$$

$$\text{Brown rice (\%)} = \frac{\text{weight of brown rice}}{\text{weight of rough rice}} \times 100$$

$$\text{Degree of milling} = \frac{\text{weight of total milled rice}}{\text{weight of brown rice}} \times 100$$

$$\text{Total milled rice (\%)} = \frac{\text{weight of total milled rice}}{\text{weight of rough rice}} \times 100$$

$$\text{Head rice (\%)} = \frac{\text{weight of head rice}}{\text{weight of milled rice}} \times 100$$

3.7.2Cooking properties

3.7.2.1Alkali spreading value

The gelatinization temperature of the endosperm starch refers to the cooking temperature at which water is absorbed and the starch granules swell irreversibly in hot water with asimultaneous loss of crystallinity and birefringence. An estimate of the gelatinization temperature is indexed by the alkali digestion test (Little *et al.*, 1958). It is measured by the alkali spreading value.

Procedure

A duplicate set of six whole milled grains without cracks were selected and placed in plastic boxes. Then 10 ml of 1.7% KOH solution was added. Rice grains were arranged to provide enough space among them to allow for spreading. Boxes were covered and kept undisturbed for 23 hours in an incubator at 30^0C. Grain appearance and disintegration were visually scored after incubation, based on the numerical scale in the following table. A scoring of 1-3 was classified as high gelatinization temperature (>74^0C), 4-5 was classified as intermediate gelatinization temperature $(74\text{-}70)^0$C and 6-7 was classified as low gelatinization temperature $(69\text{-}55)^0$C. Standard check (BR 16 variety) was included in every test (Table-3.7.1).

Table-3.7.1: Description of alkali spreading value scores for milled rice

Description	Score
Grain not affected	1
Grain swollen	2
Grain swollen, collar incomplete or narrow	3
Grain swollen, collar complete and wide	4
Grain split or segmented, collar complete and wide	5
Grain dispersed, merging with collar	6
Grain completely dispersed and disintegrated	7

3.7.2.2Cooking time

It is thattime when starche granules are fully disappear in the boiling water with increasing time (Ranghino method).

Procedure

Approximately 5g of milled rice was taken in a wire case.Then it was kept in150 ml vigorously boiled water of 250 ml beaker. Starting after 10 minutes of cooking in excess boiling water, at least 10 grains were pressed between two Petridish every minute. The grains were considered cooked when at least 90% of the pressed grains no longer show an opaque center.

3.7.2.3Elongation ratio

The principle is to presoak theuncooked rice in water, then cook the soaked rice for a set time by puttingit directly into boiling water. Elongation ratio is the ratio of length of cooked rice over the length of raw milled rice.Some milled rice show extreme elongation when cooked, especially after presoaking.Formation of transverse cracks during presoaking increase grain elongation during cooking.

Procedure

Grain elongation of rice cultivars was assessed by a simplified method (Juliano and perez, 1984). Twenty whole uncooked grains of known length were soaked in water of beakerfor 30 minutes. These presoaked rice grains were cooked for 10 minutes in boiling waterof beaker. Then these cooked rice lengths were measured. Elongation ratio was determined by mean length of 20 cooked rice grains divided by the mean length of 20 raw rice grains. The overall length of 20 grains arranged end to end for raw and cooked rice.

Calculation

Elongation ratio was calculated measuring the length of cooked and uncooked milled rice by slide calipers.

3.7.2.4Volume expansion ratio

Volume expansion ratio is the ratio of volume of cooked rice over the volume of raw milled rice. Volume expansion cooked and uncooked milled rice was measured by water displacement method.

Procedure

Fifty ml of water was taken in 100 ml measuring cylinder and 5 g raw milled rice sample was added. Initially, increase in volume of water after adding 5 g of raw milled rice was measured and noted. Raw milled rice sample was soaked for 30 minutes and cooked for 10 minutes on a water bath. Then cooked rice wastransferred into the petridish and allowed to stand for 15 minutes before analysis. Again 50 ml of water was taken in 100 ml measuring cylinder and cooked rice was added. Finally, increase in volume of water after adding cooked rice was measured and recorded.

Calculation

Volume expansion ratio was calculated by dividing the volume of cooked rice by the volume of raw milled rice in the former.

3.7.2.5Aroma

2-Acetyl-1-pyrroline is the principal aroma compound in cooked milled rice identified by Buttery *et al.,* (1982, 1983b). Retention of the volatile compound is affected by temperature during grain development, drying and storage (Itani and Fushimi, 1996).

Procedure

Rice sample of 5g was kept in a wire cage and soaked in 50ml water of 250 ml beaker for 30 minutes. After soaking, this sample was cooked for 10 minutes in an electric heater and transferred into a petridish for 20 minutes rest. Then lid of the petridish was opened and inhaled the smell to detect the aroma. The scoring of aroma on the basis of scent was done as follows (Sood *et al.,* 1978):

NS= Non Scented
MS= Moderately Scented
SS= Strongly Scented

3.8 Mineral elements

3.8.1 Estimation of phosphorus content

Estimation of phosphorus is carried out by measuring calorimetrically the yellow-orange color formed when the ash solution is treated with ammonium molybdate and the phosphomolybdate thus formed is reduced (Yoshida *et al.,* 1976).

Procedure

Approximately 0.2 g of brown rice sample was precisely weighed and put it into a 25 ml conical flask. For minerals extraction, 5 ml mixture of nitric acid:perchloric acid (5:2) was added to this flask. The sample was heated at 350^0C for digestion until the solution became clear. The digested sample was cooled and transferred into a 50 ml volumetric flask. De-ionized water was added to make the volume of 50 ml. Then the solution was filtered through a Whatman filter paper No.1 and kept it in a plastic container. One ml of extracted sample was taken into a test tube.Then 2 ml HNO_3 (2N) and 4 ml de-ionized water were added to make the volume 10 ml. Mixed the solution with vortex mixture and the absorbance was taken at 420 nm after 15 minutes. For the preparation of standard curve for phosphorus, absorbance of 0.0,0.5,1.0,2.0 and 3.5 μg ml^{-1} phosphorus solutions were used.

Calculation

$$x = \frac{y - c}{m} \text{ x } df$$

Where, x =concentration; y = absorbance; m = slope; c = intercept of the calibration curve and df = dilution factor ($\frac{\text{Volume in ml}}{\text{Weight in g}}$)

3.8.2 Estimation of calcium, magnesium, potassium, sodium, iron andzinccontent

Sample was digested and estimated by the method of the Association of Official Analytical Chemists (AOAC, 2005) and Page *et al.*, (1982).

Procedure

Approximately 0.2 g of brown rice sample was precisely weighed and put it into a 25 ml conical flask. For minerals extraction, 5 ml mixture of nitric acid:perchloric acid (5:2) was added to this flask. The sample was heated at 350^0C for digestion until the solution became clear. The digested sample was cooled and transferred into a 50 ml volumetric flask.De-ionized water was added to make the volume of 50 ml. Then the solution was filtered through a Whatman filter paper No.1 and kept it in a plastic container. Magnesium, Calcium, Ironand Zinc were determined by the atomic absorption spectrophotometer (Hitachi, 170-30)using adifferent standard curve for each. Hence, Potassium and Sodiumwere analyzed by flame photometer (Sherwood Flame Photometer 410)using adifferent standard curve for each.

Calculation

$$\text{Actual concentration (mg kg}^{-1}) = \frac{\text{Concentration in ppm x dilution factor x Volume in liter}}{\text{Weight of the sample in kg}}$$

3.9 Nutritional quality

3.9.1 Proximate composition

3.9.1.1 Determination of carbohydratecontent

The carbohydrate content of a sample was calculated by subtracting the percentage of other components of that sample (protein,fat, ash, crude fiber and moisture) from 100 (NIN, 1976).

Calculation

Percentage of carbohydrate = 100 - (protein + fat + ash + crude fiber + moisture)%

3.9.1.2Determination of protein content

Principle

Micro Kjeldahl procedure of AOAC (2005) is used for the determination of nitrogen and crude protein is calculated by multiplying the nitrogen content by a factor 5.95. Nitrogen present in the sample is converted to ammonium sulphate by digestion at 380^0C with sulphuric acid in presence of catalyst mixture. Ammonia liberated by distilling the digest with NaOH solution is absorbed by boric acid and is titrated for quantitative estimation.

Procedure

Approximately 200 mg of rice grain was taken into 100 ml Micro Kjeldahl flask. About 0.5-0.6 g of catalyst mixture and 5.0 ml of concentrated H_2SO_4 were added for digestion. Then the Micro Kjeldahl digestion flask was heated for about 1 hour until the mixture became clear in the Micro Kjeldahl digestion set up. After cooling the digested mixture, 100ml of distilled water and 9 ml of NaOH were added for distillation. Then digestion flask was carefully connected to the Micro Kjeldahl distillation set up and it was started.The distillate was collectedfor 25-30 minutes into 25 ml boric acid containing 1-2 drops of mixed indicator up to100 ml in a 250 ml conical flask.The distillate was immediately titrated with standard HCl solution to the first appearance of the violet or reddish color. Simultaneously determinate blank was used to calculate the nitrogen%in the sample.

Calculation

$$\text{Nitrogen (\%)} = \frac{(\text{ml HCl for sample} - \text{ml HCl for blank}) \text{ x HCl(N) x } 0.014}{\text{Weight of sample (g)}} \text{x } 100$$

Protein (%)= Nitrogen (%) x 5.95

3.9.1.3 Determination of fat content

Fat was extracted from the grounded rice samples with chloroform: methanol (2:1) solution. Hence, the fat was determined from the extract by the method of Choudhury and Juliano, (1980).

Procedure

About 5.0 g of dried rice flour was taken in a 150ml conical flask and 100ml of chloroform: methanol (2:1) mixture was added in this flask. Then the solution was kept incubation for overnight at room temperature and filtered through Whatman filter paper No. 42.The filtrate was taken into another conical flask of known weight. The boiling cheap was kept in this conical flask and heated until the solvent was evaporated. Then it was dried in an oven at 105^0C for 3-4 hours. After that final weight of the conical flask was taken again. Fat content was reported on a dry basis of the rice samples.

Calculation

$$\text{Fat (\%)} = \frac{\text{Final weight of the conical flasl (g)} - \text{Initial weight of the conical flasl (g)}}{\text{Weight of sample (g)}} \text{ x } 100$$

3.9.1.4 Determination of ash content

Principle

The sample is ignited at 600^0C to burn off all organic materials. The inorganic material which does not volatile at that temperature is called ash, which was determined by the method of the Association of Official Analytical Chemists (AOAC, 2005).

Procedure

The temperature of the muffle furnace was set to 600^0C and crucible was heated for half an hour. Then crucible was transferred into a desiccators, cooled and weighted (W_1). About 2g of sample (defatted) was taken into the crucible (which has previously been heated and cooled) and weighted (W_2). The sample was incinerated at 600^0C for 5 hours. The crucible was cooled in desiccators and weighted (W_3). Weight had been taken immediately to prevent the moisture absorption. The incineration was repeated until constant weight is obtained and the ash was almost white and grayish white in color. The sample was saved for mineral determination, if needed.

Calculation

$$\text{Ash (\%)} = \frac{\text{Weight of the ash (g)}}{\text{Weight of the sample (g)}} \times 100$$

$$= \frac{W3-W1}{W2-W1} \times 100$$

Where, $(W_3\text{-}W_1)$ = Weight of the ash

$(W_2\text{-}W_1)$ = Weight of the sample

3.9.1.5 Determination of crude fibercontent

The crude fiber was estimated by the method of the Association of Official Analytical Chemists (AOAC, 2005).

Procedure

About 2.0 g of rice sample was taken into a250 ml beaker and 200ml of hot sulphuric acid(0.26N) solution was added. Then the beaker was placed on a preheated hot plate of the digestion apparatus and the sample was digested for 30 minutes, rotating the beaker periodically to keep the solids or materialfrom adhering to the sides. After digestion, the sample was filtered through California modified Buchner funnel (Labconco Cat # 55100) using avacuum pump. The residue was washed with hot water until the washing is free from acid (litmus paper was used for this test). The residue (sample) was transferred again into the beaker with 200 ml of hot sodium hydroxide (0.3N) solution. The beaker was placed on a preheated heater and digested the sample for 30 minutes as mentioned above. Then filtered the sample through California modified Buchner funnel and washed the residue with hot water until the washing was free from alkali (litmus paper wasalso used for this test). Finally, the residue was washed with alcohol (about 25 ml). Then the residue was transferred into a clean porcelain crucible and dried at 100^0C for overnight. The crucible was transferred into desiccators and cooled at room temperature and weighed (W_1). Then the residue was ignited in a muffle furnace at 600^0C for 30 minutes. After that the crucible was transferred into the desiccators and cooled at room temperature and weighed (W_2).

Calculation

$$\text{Crude fiber(\%)} = \frac{\text{Weight of the crude fiber (g)}}{\text{Weight of the sample (g)}} \times 100$$

$$= \frac{(\text{W1} - \text{W2}) - \text{Blank}}{\text{Weight of the sample (g)}} \times 100$$

Where, (W_1-W_2) - Blank= Weight of the crude fiber

3.9.1.6Determination of moisturecontent

Moisture content of rice was determined by infratec^{TM}grain analyzer (FOSS).It was non-destructive method.

3.9.2Effect of processing on protein content

3.9.2.1 Milling effect

Milling effect was measured bysubtracting percent of milled rice protein frompercent of brown rice protein.

3.9.2.2 Cooking effect

Cooking effect was measured by subtracting percent of cooked rice protein frompercent of milled rice protein.

3.9.3 Determination of fractionation of protein

Principle

Fractionation of proteinwere isolated through sequentially extracting defatted brown rice powder with different solvents (rice powder to solvent ratio→1:14, w/v) according to the modified Osborne's method, (1924). It is shown in below:

Defatted brown rice powder (5.0g)

H_2O ↓

Albumins in H_2O

Residue +

5% NaCl ↓

Globulins in salt solution

Residue +

70% Ethanol ↓

Prolamins in ethanol solution

Residue +

0.05M NaOH ↓

Glutelins in NaOH solution

Residue(Mainly starch)

Procedure

Defated rice powder: Brown rice was powdered by grinding milled rice in Udy Cyclone Mill (Udy Corporation, USA) to pass through 60 meshsieve. Ten gram rice powder was taken in an extraction thimble. The thimble was bound with stand and kept in a 500 ml beaker. Then 250 ml n-hexane was taken in the beaker. A magnetic bar was kept in the beaker and the beaker was covered by the aluminum foil and kept on the magnetic stirrer. Then magnetic stirrer was turned on stirring continued for 20 hours. After that time the rice powder was free from the oil. Then the defatted rice powder was dried overnight.

Fractionation of protein: Defatted dried rice powder (5 g) was dispersed in 30 ml distilled water by stirring with a magnetic stirrer for 60 minutes. The suspension was then centrifuged at 10,000 rpm for 10 minutes and the resultant supernatant was filtered (Whatman filter paper no. 1). The residues were re-extractedtwice with 30 and 25 ml of water respectively and the recovered filtrates were combined and designated the "water-soluble fraction" (albumin). Similarly, the residue was then extracted successively with 5% NaCl solution, 70% (v/v) ethanol and 0.5M NaOH solution to separate globulin, prolamin and glutelin fractions, respectively. Albumins and globulins fractions were concentrated by dehydrating in dialysis bags with Aquacide at 0 to 4^0C. The prolamins fraction was recovered by concentrating under vacuo at 30^0C. Precipitate the glutelins by titration with 6N HCl atp^H 5.0 followed by centrifugation at 10,000 rpm for 10 min. Resuspend and wash the glutelin precipitate in acetone. Recentrifuge and dry subsequently under vacuo at 0 to 4^0C to give a powdery residue. Keep all fractions at -20^0C until further analysis.

3.9.4 Determination of amino acid composition

Amino acids were separated on a high performance anion-exchange column and directly detected them. It had advantages over pre and postcolumn derivatization methods beyond the reductions in sample preparation time and instrumentation complexity(Table-3.9.1).

Equipments

Diomex ICS-3000 ion chromatography:
GP50 Gradient pump, microbore, PEEK, with degas option
ED40 Electrochemical detector with AAA (amino acid analysis)-certified gold cell
AS50 Autosampler and thermal compartment with 25-μl injection loop
Peak Net® Chromatography workstation
Reacti-Therm™ III Heating module with Reacti-Block™H (Pierce Chemical Co.,)

Reagents and Standards

Reagents

Deionized water, 18 MΩ-cm resistance

Sodium acetate, anhydrous

Sodium hydroxide, 50%, low carbonate grade (w/w; Fisher scientific)

Hydrochloric acid, 6 N constant boiling sequential (Pierce chemical)

Standards

Amino acids in 0.1N/L hydrochloric acid; Standard reference material (National Institute of Standards & Technology)

Instrument conditions

Columns:	AminoPac®PA10 Analytical (2 x 250 mm, P/N 055406) with AminoPac PA10 Guard (2 x 50 mm, P/N 055407)
Flow Rate:	0.25 ml/min
Injection Vol:	10 µL (Full or Partial mode)
Temperature:	30^0C
Eluents:	A: Water
	B: 250 mM Sodium hydroxide
	C: 1.0M Sodium acetate
In-line Eluent Traps:	Anion Trap Column (IonPac® ATC-1, 9 x 24 mm, P/N 037151) installed between eluent bottles and degas module[6]
Typical System Operating Backpressure:	< 3000 psi

Table-3.9.1: Preparation of programmed method

Programmed method					
Time (min)	**%A**	**%B**	**%C**	**Curve**	**Comments**
Init.	76	24	0	-	Autosampler fills the sample loop
0.0	76	24	0	-	Valve from load to inject
2.0	76	24	0	1	Begin hydroxide gradient
8.0	64	36	0	8	
11.0	64	36	0	8	Begin acetate gradient
18.0	40	20	40	8	
21.0	44	16	40	5	
23.0	14	16	70	8	
42.0	14	16	70	8	
42.1	20	80	0	5	Column wash with hydroxide
44.1	20	80	0	5	
44.2	76	24	0	5	Equilibrate to starting condition
75.0	76	24	0	5	End of run
On-line Degas:	30 sec every 4 min				
Detection:	Integrated pulsed amperometry AAA-Certified gold cell (P/N 055832); Ag/AgCl reference electrode, p^H reference mode				

Sample preparation

For amino acid analysis, 0.5 g of sample was weighed and makes a fine pest by mortar pestle with adding about 50 ml HCl (6N) and then filtered through markin clothes. The liquid portion was transferred into a 250 ml round joint bottle flask and was placed on Heating Mantle at 70^0C and condensed by tape water for 22 hours. Afterwards, the acid was evaporated on a water bath and volume was made 25 ml by HCl (0.1N) and filtered through Whatman filter paper No. 42.

Amino acid standard preparation

The amino acid standard mix, obtained from the National Institute of Standards & Technology (NIST), consists of 17 amino acids (but not Trp). Each amino acid concentration is defined on the certificate of analysis.

The solution was ready for analysis and run through the Dionex Ion Chromatography [Chromeleon (c) Dionex 1996-2006,Version 6.80 SR9a Build 2680 (163077)]. Standard amino acids mixture was also run under identical conditions to identify the compounds. Compound retention times and areas (peak) for samples and standard amino acids were automatically recorded. By comparing the two peak areas, the amount of amino acids were calculated.

3.9.5Determination of protein digestibility

In vitro protein digestibility was assessed by employing pepsin and pancreatin (Akeson and Stahmann, 1964). The nitrogen contents of the sample and the undigested residue were determined by the Micro Kjeldahl method (AOAC, 2005).

Procedure

At first 2g rice powder was taken in 100 ml conical flask. Then 50 ml chloroform was poured in this conical flask. A magnetic bar was kept in it and mouth of the flask was covered by the aluminum foil. After that, conical flask was kept on the plate of the magnetic stirrer. Then switch on the stirrer and sample was kept for 16 hr due to de-fated rice powder. After 16 hr de-fated rice powder was filtrated with filter paper Whatman No.1 and was dried for 30 minutesin open space.

In vitro protein digestibility was determined by the method described by (Singh *et al.*, 1982). Instead of using two enzymes only single enzyme was used. Approximately 400 mg de-fated powder of each rice cultivars was taken in screw cap tube. Then 5ml pronase solution and few drops of chloroform were added to this screw cap tube. Then this tube was incubated at temperature of 37^{0}C for 24 hr under shaking condition. After 24 hr the reaction was terminated by adding 7 ml of 10% trichloro acetic acid (TCA) solution. The suspension was centrifuged for 15 minutes at 10,000 rpm. The residue was washed twice with 5ml of 5% TCA. Finally, the residue was collected for residual nitrogen by using micro kjeldal method and then residual protein was calculated. The digested protein of the rice sample was calculated by subtracting residual protein (non-digested protein) from total protein of the rice sample.

Calculation

$$\text{Protein digestibility}(\%) = \frac{\text{Digested protein}}{\text{Total protein}} \text{x } 100$$

3.9.6Determination of starchdigestibility

Starch represents an energy reserve stored in plants. In rice starch is deposited in the kernels mainly in the endosperm in the form of granules. Starch, essentially an α-glucan polymer, is composed of two components: a linear fraction, amylose and its branched counterpart, amylopectine. Both fractions are large polymers of glucose units held together by glycosidiclinkages. Native starches, which are insoluble in water (Miles *et al.,*1985), are rarely consumed by humans. Almost all starches are eaten by heat treatment, which changes the structure and properties of the starch remarkably.

Procedure

Rice flour of 100 mg was weighted precisely and taken in a 100 ml conical flask. 25 ml distilled water was added to it. Due to starch gelatinization conical flask was kept in a boiling water bath for 30 minutes. After cooling, buffer was added to make the volume of 100 ml and it was placed in a shaking water bath (50-55)^{0}Cfor equilibrium temperature. After equilibration, amyloglucosidase solution was added to the sample in a conical flask and 0.5 ml sample was pippeted out immediately into a test tube for zero time digestion. Then 0.5 ml solution waspippeted outinto each test tube at 20 minutes and 120 minutes interval respectively. All sample tubes were covered immediately with aluminum foil and transferred in the boiling water bath for 10 minutes heating. After cooling, 2.5 ml of distilled water was added to each sample tube for dilution and mixed well by vortex mixture. Then 0.5 ml from supernatant was taken precisely in a new test tube accordingly. For preparation of glucose standard solution,0.2 mg of dried glucose was weighted precisely and taken in a 100 ml volumetric flask. Distilled water was added to make the volume of 100 ml and mixed well.Then 0 ml, 1 ml, 2 ml, 3 ml, 4 ml and 5 ml standard stock solution were added to each test tube accordingly and distilled water was added to make the volume of 10 ml for all tube. After that 0.5 ml from supernatant was pippeted out in a new test tube accordingly.For color development 2 ml of 3,5-dinitro salicylic acid (DNS) was added to each sample and standard tubes. These tubes were covered with aluminum foil, mixed well immediately and transferred in the boiling water bath for 10 minutes heating. After cooling 10 ml distilled water was added and mixed well by vortex mixture. Absorbance was measured at 520 nm in aspectrophotometer.

Calculation:

$$\text{Starch digestibility (\%)} = \frac{\text{Std. factor x O.D x Total dilution x 0.9 x 100}}{\text{Weight of the sample}}$$

3.10 Genetic diversity of *Waxy* gene

3.10.1Chemical method: Determination of amylose content

Principle

Amylose in rice is released by treatment with dilute alkali. By the addition of Tri-iodide ion, amylose produces blue color. The absorbance of blue color produced in aqueous solution is measured by UV-spectrophotometer at 620 nm as described by Williams *et al.,* (1958) as modified by Juliano, (1971).

Procedure

Approximately 100 mg of rice flour of each sample was weighed accurately and placed into a 100 ml volumetric flask (in duplicate).Then 1 ml of 95% ethanol was added carefully to disperse the flour. After adding 9 ml of 1N NaOH, the flask was kept overnight at room temperature(heated in water bath for 10 minutes) to gelatinize the starch. Sample was diluted to 100 ml with distilled water. Later, 5 ml of sample solution was pipetted out (transferred) into another 100 ml volumetric flask and 1 ml of acetic acid was added to acidify the solution along with 2 ml of iodine solution. Then distilled water was added to make the volume of 100 ml. After this the solution was mixed well with shaking and kept it for 20 minutes. Similarly, standard samples were prepared. Absorbance of the sample was measured at 620 nm by UVspectrophotometeragainst the blank solution. Amylose content of different rice cultivars was determined with the help of standard curve. Results were expressed as percent amylose content in milled rice weight.

3.10.2Plant materials

Local cultivars (109) and HYVs (20) of rice were screened on the basis of agronomic and morphological characters, physicochemical properties, milling and cooking properties, mineral elements as well as nutritional quality.After screening, 35 rice cultivarswere subjected to genetic diversity.For DNA isolation,rice cultivars were grown under standard net-house conditions and 3-4 weeks old seedlings were harvested.

3.10.3 Genotyping methods

3.10.3.1DNA isolation from plant tissue by using CTAB method

Around 1.0g of leaves from 10-20 seedlings of each rice cultivar was kept in liquid nitrogen and then crushed with liquid nitrogenin a mortarto get very fine powder. The powder of each cultivar was transferred directly with spatula into the individual preheated screw cap tube containing 5ml CTAB (Cetyl Trimethyl Ammonium Bromide) buffer solution and 10µL 2-mercaptoethanol. The samples were mixed gently, thoroughly and then incubated at 65^{0}C in water bath for 30 minutes. After 5 minutes interval ups and downs was done. Then 5ml of the mixture of phenol:chloroform: isoamyl alcohol (25:24:1) was added to each screw cap tube and mixed gently.The screw cap tubes were centrifuged at 4000 rpm for 15 minutes.Around 4.5 ml of the upper aqueous phase was transferred into the fresh screw cap tube by wide pipette. Then 2/3 volume of ice cold isopropanol was added to each screw cap tube and mixed gently to precipitate DNA.The screw cap tubes were kept at -20^{0}C for overnight. Next day the screw cap tubes were centrifuged at 4000 rpm for 15 minutes again and the supernatant was discarded. Pellet was shown in the screw cap tube and washed with 5ml 70% ice cold ethanol. The screw cap tubes were centrifuged at 4000 rpm for 5 minutes and the supernatant was discarded.For air-dried screw cap tubes were kept at room temperature for overnight. Next day dried pellet was dissolved in 800µLTris-EDTA solution.In eachscrew cap tube20µL RNase was added and screw cap tubes were incubated at 37^{0}C for 30minutes.Equal volume of (phenol: chloroform: isoamyl alcohol)solution was added into the screw cap tubes and the screw cap tubes were centrifuged at 4000 rpm for 15 minutes again. In each new eppendrof 600µL upper aqueous phase was taken and equal volume of(chloroform: isoamyl alcohol) solution was added into the screw cap tubes and the screw cap tubes were centrifuged at 10000 rpm for 20 minutes. In each eppendrof 400µLupper aqueous phase was taken and 1/10 volume of 3M, Na-acetate and double volume of 99% ice cold ethanol was added.The mixture was kept at -20^{0}C for overnight. Next day the mixture was centrifuged at10000rpm for 15 minutes.The supernatant was discarded, washed with 1ml 70% ice cold ethanol and the mixture was centrifuged at10000rpm for 10 minutes. Againthe supernatant was discarded, washed with 1ml 70% ice cold ethanol and the mixture was centrifuged at10000rpm for 5 minutes. Finally, the supernatant was discarded and the pellet was kept at overnight for completely dry. Next day dried pellet was dissolved in (30-40)µLof PCR graded Tris-EDTA.

3.10.3.2Quality assessment and quantification of DNA

The quality of DNA is very important to obtain good results and for long-term storage. It is also important to know the exact concentration of the DNA, which isused later for correct PCR amplification.

3.10.3.3Quantification of DNA by nanodrop spectrophotometer

This special spectrophotometer can measure the concentration of nucleic acid (DNA and RNA), protein samples and other. It also ensures the quality of the samples by drawing the standard curve. The procedure to measure the concentration of DNA is given below.

Procedure

The spectrophotometer was selected to measure nucleic acid sample. The wavelength was fixed at 260 nm and 280 nm for nucleic acid analysis.The nozzle of the machine was first cleaned with soft tissue paper and was initialized with PCR graded water.The blank was set with appropriate buffer which was used to dissolve the DNA (TE buffer was used here). Then 1 µL of sample DNA from each tube was loaded on the nozzle one by one. The lid was then closed and OD was measured.The machine showed the concentration of the sample in ng/µL as well as its standard curve with the absorbance ratio of 260nm and 280nm.

3.10.3.4 Comparison of sample DNA with λ DNA standard

Three µL of DNA dye was mixed with 1 µL of isolated DNA of each variety. Then 4µLmixture of each variety was loaded in the wells of 0.8% agarose gel followed by 50ng and 100ng of λ DNA standard.Electrophoresis and staining with ethidium bromide was carried out. DNA concentration was estimated by visual comparison of the fluorescence of each sample with the standard (50ng and 100ng of λ DNA)under UV light.The quality of the samples was also checked by observing any smear of degraded DNA or lower size bands of RNA.

3.10.4 Genetic diversity of *Waxy* gene for rice cultivars with SSR markers

3.10.4.1 Primers

Total 2 pairs of SSR primers were used to amplify isolated DNA from the leaves. SSR markers are very useful markers. Each primer-pair typically identifies a single locus, which have many alleles because of the high mutability of SSR loci and thus show polymorphism. The amplified products are from 80bp to 350bp. Variation between polymorphic bands may be as little as 4bp. So, non-denaturing polyacrylamide gel electrophoresis was used.

First pair of primer(First pair of primer had 124bp.)

Oligo name	Sequence	Length	Tm(^{0}C)	GC%
RM190F	CTTTGTCTATCTCAAGACAC	20	56	40.0
RM190R	TTGCAGATGTTCTTCCTGATG	21	61	42.9

Second pair of primer(Second pair of primer had 252bp. Cutting site of this pair of primer was 124bp and 128bp.)

Oligo name	Sequence	Length	Tm(^{0}C)	GC%
RM190F	CTTTGTCTATCTCAAGACAC	20	56	40.0
GBSSW2R	TTTCCAGCCCAACACCTTAC	20	64	50.0

3.10.4.2 Preparation of the master mixture

Master mixture was prepared for 40 reaction samples containing buffer, dNTPs, Mg2+, specific primer pairs and Taq polymerase in a sterile 1.5ml eppendrof tube(Table-3.10.1).

Table-3.10.1: Preparation of master mixture for PCR

Components	1 reaction (µL)	40 reactions (µL)
PCR buffer (10X)	1.5	60.0
dNTPs (10mM)	1.5	60.0
$MgCl_2$(25mM)	1.0	40.0
Forward primer (50ng/µL)	0.5	20.0
Reverse primer (50ng/µL)	0.5	20.0
Taq DNA polymerase	0.5	20.0
Total	**5.5**	**220.0**

3.10.4.3PCR reaction preparation

At first genomic DNA, 20% DMSO and autoclaved ultra-pure water were dispensed in the labeled PCR tubes. The mixture of this PCR tubewas then denatured at 95^0C for 5 minutes and immediately transferred into ice for 1 minute.After mixing and spin, 5.5µL of the above master mixture was added to each PCR tube which was prepared previously.Taq DNA polymerase was added to the tubes just before start the reaction.Finally the tubes were subjected to spin and transferred to thermocycler for the amplification reaction(Table-3.10.2).

Table-3.10.2: Preparation of samples and control tube with DNA, DMSO and ddH_2O

Tube	DNA(50ng/µL)	DMSO (20%)	ddH_2O	Total Volume
Sample tube	1.0 µL	2.0µL	6.5µL	9.5µL
Control tube	0.0µL	2.0µL	7.5µL	9.5µL

3.10.4.4 Thermal cycling profile used in PCR

The thermal cycling profile program in PCR machine to amplify the gene by polymerase chain reaction (PCR) for 35 cycles had shown (Table-3.10.3).

Table-3.10.3: Thermal cycling program for PCR amplification

Steps	Temperature(^{0}C)	Time(minutes)	No. of cycles
Hot start to activate the taq.polymerase	95	5	1(First)
Denaturation	95	1	35
Annealing temperature	55(adjustable)	1	
Elongation	72	1	
Final extension	72	7	1(Last)
Hold	4	**For ever**	

3.10.4.5 Visualization of the amplified products

The amplified PCR products was resolved and visualized with the help of agarose gel electrophoresis or polyacrylamide gel electrophoresis. Type of gel selection depends on the length and nature of the amplified products.

3.10.4.6Concentration check of the PCR product

The purity and concentration of amplified product can be checked from the band in agarose gels. For this 0.8% agarose is ideal. Concentration was estimated by using known concentrations of bacteriophage lambda DNA (50ng/μL).

Procedure

According to the percentage and the amount of gel desired, the appropriate weight of agarose was taken in a conical flask and then 1x TAE buffer of required volume was added.The flask was placed in a microwave on high temperature for 2-3 minutes until the gel solution was completely clear.The solution was air-cooled until the temperature was below 60^0C.The cooled solution was poured into the gel trayand the comb was assembled for wells formation. It was made sure that there was no bubble around the comb. The gel was kept approximately 30-45 minutes to be solid form. The gel tray was placed in the tank filled with 1x TAE buffer and enough 1x TAE buffer was added to keep it over the gel tray. The PCR product and DNA dye were mixed well and loaded in the wells of the gel. At the end of the loaded samples, 2µL of λ (lamda) DNA was loaded to check the PCR product. The gel tank was covered with lead and the power supply was turned on. 100Volt was applied and the electrophoresis was done until the blue dye was run 3/4 (three fourth) of the length of the gel, then the power supply was turned off.The gel was stained in ddH_2O containing ethidium bromide (0.5 μg/ml)for 30-45 minutes at room temperature.Photograph of the gel was taken under UV illuminationusing AlphaEase FC Imaging System.

3.10.5 Polyacrylamide gel electrophoresis (PAGE)

Polyarylamide gel has much higher resolution than the agarose gel. Depending on the polymorphic nature, different concentrations (6-10)% of polyacrylamide gel were used for easy analysis and scoring (Table-3.10.4).

Table-3.10.4: Preparation of polyacrylamide gel (10%, 2 gels)

Ingredient	Volume
40% acrylamide	25 ml
5X TBE	4 ml
ddH_2O, volume up to	100ml
10% APS	1000μL
TEMED	85μL

Procedure

Both glass plates were cleaned carefully by 99% ethanol and were assembledby placing both cleaned surface inside with spacers (~1.5 mm thick) and elastic gasket as a sealer surrounding the edges of glass plate.The assembly was leveled and checked for leakage with ddH_2O.The gel was poured in the gel case and the comb was assembled for wells formation. The gel was allowed to solidify for ~1 hr. The combs were removed and sandwich glass plate/gel was attached with the electrophoresis apparatus.The PCR product(15μL) was mixed well with sequencing dye(5μL).From the mixture, 4 μL was generally loaded into the well of polyacrylamide gel very carefully to prevent cross contamination.Electrophoresis was carried out in 1XTBE buffer at 100W for 2 hours or up to the time when the bromophenol blue traveled a satisfactory distance.The electric current was turn off and both glass plates were disassembled. Elastic rubber and spacers were removed.The gel was stained in ddH_2O containing ethidium bromide (0.5 μg/ml) for 30-45 minutes at room temperature.Photograph of the gel was taken under UV illumination using Alpha Ease FC Imaging System.Polymorphic band patterns visualized in the gel was photographed using highly sophisticated Alpha Ease FC imaging system using UV-automatically adjusted UV illumination. Polymorphism among the cultivars were scored according to their molecular weight on gel by the Mol Weight Analysis tool of Alpha Ease FC imaging system which showed the band size of the products after comparison with the known size of a marker ladder, in this case a $1kb^+$ and 20-200bp ladder were used.

3.10.6Genetic diversity for*Waxy* gene of rice germplasm with restriction digestion

Restriction endonuclease is called the molecular scissor. It can cut DNA by recognizing a specific sequence.The G/T polymorphism in intron 1 of the *Waxy* gene (In1G and In1T alleles) was determined by restriction enzyme digest of a polymerase chain reaction (PCR) fragment generated from this genomic region. Specifically, the DNA fragment containing the polymorphic sequence of In1 SNP was amplified from genomic DNA using forward primer RM190F and reverse primer GBSSW2R.The PCR reaction was discussed previously. After PCR, setting up a restriction enzyme digest was shown below.

Sl. No.	Component	Volume(µL)
1	PCR greaded H_2O	7.15
2	RE 10X Buffer	1.0
3	Acetylated BSA	0.1
4	PCR product	1.5
5	Restriction enzyme, *AccI* (mixed well by pipetting)	0.25

Procedure: The above mixture was incubated for 1 hr at 37^0C. Agarose gel of 2%with wells was prepared and placed in the tank filled with 1x TAE buffer.The digested mixture and DNA dye were mixed well and loaded in the wells of the gel. At the end of the loaded samples, 2µL of 1 Kb^+ladder was loaded to detect the bend of the digested product.The gel tank was covered with lead and the power supply was turned on. 100V was applied and the electrophoresis was done until the blue dye was run 3/4 (three fourth) of the length of the gel, then the power supply was turned off.The gel was stained in ddH_2O containing ethidium bromide (0.5 µg/ml) for 30-45 minutes at room temperature.Photograph of the gel was taken under UV illuminationusing AlphaEase FC Imaging System. The amplified PCR product size was 252bp and the cutting site of it was 124bp and 128bp.

3.11Hybridization

Parents were seeded in BRRI farm, Gazipur in 3 sets starting from 20^{th} April, 2012 with an interval of 10 days to synchronize flowering times for achieving desired cross combinations. BRRI dhan28 and BRRI dhan55 were used as recipient (donar) parent. Twenty four days old seedlings were transplanted @ single seedling with a spacing of 25 cm x 15 cm in a 5.4 m x 2 m rows plot. Fertilizers @ 80: 60: 40: 100: 10 kg N, P_2O_5, K_2O, Gypsum and $ZnSO_4$/ha were used. Nitrogen was applied at split application at 15, 30 and 45 DAT. Total amount of P_2O_5, K_2O, Gypsum and $ZnSO_4$ were applied at the time of final land preparation. Crop management such as weeding, controlling disease and insect pests were done in time. At flowering stages several crosses were made but from only three single crosses (Motichak × BRRI dhan28, Magoibalam × BRRI dhan55 and Molladigha × BRRI dhan28) got sufficient F_1 seed. To confirm the F_1 seeds as true hybrid F_1 seeds of each cross and its respective parents were germinated in petridishes and then sown in pots with soil in the following season. Nineteen days old seedlings were transplanted with single seedling/hill at a spacing of 20 cm x 15 cm in the net house. Respective parental seedlings were transplanted on both sides of F_1 in different earthen pots. List of parents of hybridization are shown (Table-3.11.1).

Table-3.11.1: List of usable parents for hybridization

SI.No.	Selected parents	Characteristics
1	Boradudhkalam	High 1000-grain wt. (38.1g)
2	Dudhkalam	High 1000-grain wt. (37.0g)
3	Molladigha	High protein, High 1000-grain wt. (34.3g)
4	Neda	High protein
5	Magoibalam	High protein
6	Boylam	High protein
7	Motichak	High protein
8	Patnai-231	High amylose
9	Depa	High amylose
10	Poushmorich	High amylose
11	Karailadhan	High amylose
12	BRRI dhan28	High yielding variety with fine medium grain
13	BRRI dhan55	High yielding variety with fine long grain

3.12 Statistical analysis

All data were arranged for computation in Microsoft Excel softwares. The data of least significant difference for all parameters was analyzed for ANOVA by CropStat software of IRRI (www.irri.org). Least Significant Difference (LSD) test was carried out for separating means. Correlation coefficient and dendrogram were done through SPSS v17.0 software for Pearson correlation and hierarchical cluster (Gomez and Gomez, 1984). Correlation analysis always helps the consumers to select better rice varieties for their consumption and use (Seraj *et al*., 2013).

Chapter 4

RESULTS

4.1: Evaluation of agronomic characters for long, medium and short grain rice cultivars

4.1 Agronomic characters

In total, 129 rice cultivars including109 local rice cultivars and 20 HYVs (BRRI varieties) of rice have been evaluated by agronomic traits such as yield, thousand grain weight, number of tiller per hill, number of panicle per hill, panicle length, plant height, growth duration and percent of filled grains.

4.1.1 Grain yield

Grain yield is the main trait for yield contributing factors. The grain yield of the tested 109 local rice cultivars varied from 0.9 t/ha to 5.2 t/ha where 20 HYVs were used as check. BRRI dhan49 of medium grain had the highest yield (5.6 t/ha) which was very close to the Dudhkalam of long grain local rice cultivar (5.2 t/ha). Prominent high yield local rice cultivar, Boradudhkalam of long grain yielded 4.9 t/ha which was similar to the BRRI dhan41 of long grain (4.9 t/ha). Other prominent high yield cultivars, Tilokkajal of medium grain local rice cultivar, gave 4.5 t/ha which was similar to the BR4 of medium grain and BRRI dhan39 of long grain but lower than the BR10, BRRI dhan40, BRRI dhan44 and BRRI dhan46 of medium grain yielded (4.6-4.8) t/ha. Some other important high yield local rice cultivars including Ganjia, Patnai-231, Kajalsail, Jhoshua, Kanaibansi, Harilaxmi, Gohatibinni, Gojalgoria and Shata yielded (4.0-4.3) t/ha which was very close to the BR22, BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan32 and BRRI dhan38 (4.0-4.4) t/ha. Some prominent intermediate yield local rice cultivars including T.R.Aman, Dudsail, Hijli, Pakhisail, Lalsoru and Lalbinni yielded (3.8-3.9) t/ha which was higher than the mega variety, BR11. Other important intermediate yield local rice cultivars including Kalabinni-1, Hatisail, Jol and Nakchi gave the similar yield like mega variety having the yield of 3.7 t/ha. Some other intermediate yieldlocal rice cultivars including Betudhan, Kharmao, Bariksail, Shithabhog, Lohasail, Kanaklata, Athabinni, Karailadhan, Malsira and Putidepa yielded (3.5-3.6) t/ha which was higher than the aromatic variety, BR5. Other intermediate yield local rice cultivars including Pajam, Gurdoi, Poushmoricha, Tulsimala, Hashfol and

Cylindrical Tapi-629 gave 3.4 t/ha yieldlike BR5 (3.4 t/ha). Few local rice cultivars such as Sorukamina, Changai, Maloti, Bhorochalam, Nariabochi and Jhingasail-2 gave 3.3 t/ha which was as same as monga mitigated variety (BRRI dhan33) and fine grain variety (BRRI dhan37). Local rice cultivars of Redpiebald-219, TK deep straw Tapl-773, Somondori, Kumragoir, Nizersail, Binniphul, Chinisagor, Lalsaru, Khorma, Hathazi and Khasha yielded (3.0-3.2) t/ha. Many local rice cultivars such as Chunikanai, Tilkapur, Sadajira Tapl-321, Depa, Michisail, Dholagachha, Jabsira, Shamrosh, Pakibiroin, Rangabinni, Malagrosa, Chinigura, Dudsar Tapal-146, Binni-1, Najirsail, Ledabinni, Kataribhog-1, Lalmota, Jirakatari-1, Sadamota and Kalasaru yielded (2.8-2.9) t/ha which was higher than the another aromatic variety, BRRI dhan34. The lowest range of the intermediate yield local rice cultivars including Murchmut, Paharisail, Kalimanik, Kalijira, Kataribhog-2, Gobcha, Binni-2, Bolonga, Topaboro, Joyna, Molladigha, Uknimadhu, Minki, Dadkhani, Nunia, Kalabinni-2 and Nurior yielded (2.0-2.3) t/ha which was very close to the BRRI dhan34 (2.3 t/ha). Local rice cultivars of Kataribhog-232, Joalbagh, Baoijhaki, Laxmikajol, Chamara, Surjyamukhisangla, Motichak, Lathamona, Jirakatari-2, Kalisayta, Rahikhama, Rajamora, Jingasail-1, Boylam and Neda yielded(1.1-1.9) t/ha. Magoibalam gave the lowest yield of 0.9 t/ha. Among the local rice cultivars, 12 cultivars were high yield, 81 intermediate yield and 16 low yield (Table-4.1.1a, Table-4.1.1b and Table-4.1.1c).

Among the 32 long grain local rice cultivars, Dudhkalam yielded the highest of 5.2 t/ha but Neda yielded the lowest of 1.1 t/ha. Dudhkalam, Patnai-231, Boradudhkalam, Kanaibansi, Harilaxmi, Gohatibinni and Shata, having long grain cultivars had >3.9 t/ha yield (Table-4.1.1a). Among the 48 medium grain local rice cultivars, Tilokkajal yielded the highest of 4.5 t/ha but Magoibalam yielded the lowest of 0.9 t/ha. Tilokkajol, Ganjia, Jhoshua, Gojalgoria and Kajalsail of medium grain cultivars had >3.9 t/ha yield. Magoibalam had been affected by Golmig and Steamborar at primary tillering stage. Sumithion (50c.c) was applied for Golmig and Foradon (5 g) was applied for Stemborar all over the field (Table-4.1.1b). Among the 29 short grain local rice cultivars, Dudsail yielded the highest of 3.9 t/ha but Rahikhama yielded the lowest of 1.5 t/ha (Table-4.1.1c). Long, medium and short grain local rice cultivars gave the lower mean of yield than long, medium and short grain HYVs (Figure-4.1.1a). Grain yield of the rice cultivars was classified as high yield (>3.9 t/ha), intermediate yield (2.0-3.9) t/ha and low yield (<2.0t/ha). In the long and medium grain rice cultivars, 31% and 26% high yield had at the level of >3.9 t/ha. Accordingly, 58%, 63% and 84% intermediate yield in long, medium and short grain ricecultivarshadat the level of (2.0-

3.9) t/ha. Similarly, 11%, 11% and 16% low yield in long, medium and short grain rice cultivarshadat the level of <2.0 t/ha (Figure-4.1.2a).

4.1.2 Thousand grain weight

Another important trait of yield contributing factorsis thousand grain weight. Thousand grain weight of the tested 109 local rice cultivars varied from 10.3 g to 38.1 g where 20 HYVs were used as check. In the local rice cultivars, Boradudhkalam of long grain gave the highest thousand grain weight (38.1 g) but Jirakatari-1 of short grain gave the lowest thousand grain weight (10.3 g). Dudhkalam and Molladigha of long grain local rice cultivars had the second and third highest position having the thousand grain weight of 37.2 g and 34.3 g respectively. Most of the prominent cultivars were Kalabinni-1, Nakchi, Cylindrical Tapi-629, Sadamota, Rajamora, Kajalsail, Shithabhog, Depa, Jol, Hatisail, Kalimanik, Lalmota, Tilokkajal, Jhingasail-2 and Pakhisail having the range of thousand grain weight of (30-32.9) g which was obviously higher than the BRRI dhan44 (29.9 g). Cultivars of Patnai-231 and Hathazi both had the thousand grain weight of 29.1 g which was very close to the BRRI dhan40 (29.3 g). Other prominent cultivars were Pakibiroin, Motichak, Shata, Athabinni and Putidepa having the range of thousand grain weight of (27.1-27.7) g which was almost similar to the BRRI dhan31 (27.3 g)but lower than the BR23 (28.2 g). Some important cultivars were Dudsar Tapal-146, Gohatibinni, TK deep straw Tapl-773, Kumragoir, Bhorochalam, Minki, Changai, Joyna, Kharmao and Sadajira Tapl-321 having the range of thousand grain weight of (26.0-26.7) g as like as BRRI dhan46 (26.2 g). Other cultivars such as Betudhan, Joalbagh, Binni-1, T.R.Aman, Kalisayta, Harilaxmi, Gobcha, Lohasail, Kanaibansi, Boylam, Karailadhan, Hashfol and Shamrosh had the range of thousand grain weight of (25.0-25.9) gas like as BRRI dhan41 (25.5 g) and BRRI dhan39 (25.1 g). Few cultivars such as Chamara, Ledabinni, Nariabochi, Dholagachha, Redpiebald-219, Jingasail-1 and Binni-2 having the range of thousand grain weight of (24.1-24.8) g had almost the similar result of monga mitigated variety, BRRI dhan33 (24.5 g). Cultivars of Lathamona, Jhoshua, Khorma, Gojalgoria, Tilkapur, Lalbinni and Poushmoricha having the range of thousand grain weight of (23.3-23.9) g had almost the similar result of BRRI dhan30 (23.4 g). Some cultivars such as Rangabinni, Magoibalam, Paharisail, Jabsira, Topaboro, Murchmut, Malsira, Maloti, Somondori and Kalabinni-2 having the range of thousand grain weight of (21.0-22.4) g as like as BRRI dhan32, BRRI dhan37 and mega variety (BR11) having the range of thousand grain weight of(21.0-22.2)g. Few other cultivars such as Nurior, Bolonga, Rahikhama and Bariksail having the range of thousand grain weight of (20.1-20.8) g which was very close to that of BR4, BR10, BR22, BR25, BRRI dhan38 and BRRI dhan49having the range of thousand grain weight of(20.0-20.8) g. Nunia, Najirsail, Neda, Tulsimala, Nizersail, Hijli, Pajam, Kanaklata, Ganjia, Baoijhaki, Dadkhani, Kataribhog-1, Dudsail, Gurdoi, Kataribhog-2, Kataribhog-232, Lalsoru and Malagrosa type of rice cultivars were very fine grain having the range of thousand grain weight of (13.4-19.2) g. So, these cultivarswith high priceare demandable in our national market for daily consumption of urban people. Some important cultivars including Binniphul, Jirakatari-2, Chinisagor, Kalasaru, Chinigura, Lalsaru, Michisail, Chunikanai and Khasha had the range of thousand grain weight of (11.2-12.9) g which was very similar to that of BR5 (12.2 g). These cultivars are used as special dish.Most desirable kalijira type rice cultivars are used as special dish for special occasion in Bangladesh owing to their very low thousand grain weigh (<11 g). Following cultivars including Kalijira, Sorukamina, Uknimadhu, Surjyamukhisangla, Laxmikajol and Jirakatari-1hadthe range of thousand grain weight of (10.3-10.9) g which was similar to that of BRRI dhan34 (10.8 g).Among the local rice cultivars, 20 had very high thousand grain weight, 28 had high thousand grain weight, 28 had intermediate thousand grain weight, 13 had low thousand grain weight and 20 had very low thousand grain weight (Table-4.1.1a, Table-4.1.1b and Table-4.1.1c).

Among the 32 long grain local rice cultivars, Boradudhkalam had the highest thousand grain weight (38.1 g) but Neda had the lowest of 18.1 g (Table-4.1.1a). Among the 48 medium grain local rice cultivars, Nakchi had the highest thousand grain weight (31.7 g) but both Lalsoru and Kataribhog-232 had the lowest of14.7 g (Table-4.1.1b). Among the 29 short grain local rice cultivars, Minki had the highest thousand grain weight (26.2 g) but bothLaxmikajol and Jirakatari-1 had the lowest of 10.3 g (Table-4.1.1c). Long, medium and short grain local rice cultivars had the higher mean of thousand grain weight than long, medium and short grain HYVs (Figure-4.1.1a). Thousand grain weight of the rice cultivars was classified as very high thousand grain weight (>27 g), high thousand grain weight(25-27) g, intermediate thousand grain weight (20-24) g, low thousand grain weight(15-19) g and very low thousand grain weight (<15) g. In the long and medium grain rice cultivars, 36% and 18% very high thousand grain weighthad at the level of >27 g. Accordingly, 44%, 21% and 7% high thousand grain weight in long, medium and short grain rice cultivars had at the level of (25-27) g. Differently, 17%, 42% and 19% intermediate thousand grain weight in long, medium and short grain rice cultivarshadat the level of (20-24) g as well as

3%, 13% and 13% low thousand grain weightinlong, medium and short grain rice cultivarshadat the level of (15-19) g. In the medium and short grain rice cultivars, 6% and 61% very low thousand grain weight had at the level of <15 g (Figure-4.1.2a).

4.1.3 Number of tiller/hill

Number of tiller/hill of the tested 109 local rice cultivars varied from 9 to 17 where 20 HYVs were used as check. One hundred and four cultivars had intermediate tillering (producing) ability but only 5 cultivars had low tillering (producing) ability. Among the intermediate tillering ability, Najirsail of medium grain and Topaboro of short grain local rice cultivars had the highest number of tiller/hill (17). Then Kataribhog-232 of medium grain cultivars had 16 number of tiller/hill as well as Depa of long grain and Kataribhog-1 of medium grain both cultivars had15 number of tiller/hill. These local rice cultivars had higher number of tiller/hill than the HYVs. Sixteen cultivars had 14 number of tiller/hill as like as BRRI dhan32, BRRI dhan38 and BRRI dhan49. Seventeen cultivars had 13 number of tiller/hill as like as BR5 and BR10. Twenty two cultivars had 12 number of tiller/hill as like as BR22, BR25, BRRI dhan31 and BRRI dhan33. Thirty six cultivars had 11 number of tiller/hill as like as BR4, BR11, BRRI dhan30, BRRI dhan34, BRRI dhan37, BRRI dhan40, BRRI dhan44 and BRRI dhan46. Twenty eight cultivars had10 number of tiller/hill as like as BR23, BRRI dhan39 and BRRI dhan41. Cultivars of Molladigha, TK deep straw Tap-773, Shata, Motichak and Murchmut had low tillering ability (9) (Table-4.1.1a, Table-4.1.1b and Table-4.1.1c).

Among the 32 long grain local rice cultivars, Depa had the highest number of tiller/hill (15) but Molladigha, TK deep straw Tapl-773 and Shata had the lowest number of tiller/hill (9). All long grain local rice cultivars had intermediate tillering ability except above 3 cultivars which had low tillering ability (Table-4.1.1a). Among 48 medium grain local rice cultivars, Najirsail had the highest number of tiller/hill (17) but Motichak had the lowest number of tiller/hill (9). All medium grain local rice cultivars had intermediate tillering ability except Motichak which had low tillering ability (Table-4.1.1b). Among 29 short grain local rice cultivars, Topaboro had the highest number of tiller/hill (17) but Murchmut had the lowest number of tiller/hill (9). All short grain local rice cultivars had intermediate tillering ability except Murchmut which had low tillering ability (Table-4.1.1c). Long grain local rice cultivars showed the higher mean of number of tiller/hill than that of long grain HYVs. Medium and short grain local rice cultivars showed slightly lower mean of number of tiller/hill than medium and short grain HYVs (Figure-4.1.1a). Total number of tiller/hill of the rice cultivar was classified as high tillering ability (>19), intermediate tillering ability (10-19) and low tillering ability (<10). In long, medium and short grain rice cultivars, 92%, 98% and 97%intermediate tillering ability had at the level of (10-19). Differently, 8%, 2% and 3% low tillering ability in long, medium and short grain rice cultivarshadat the level of <10. But high tillering ability (>19) was not foundin long, medium and short grain rice cultivars (Figure-4.1.2a).

4.1.4 Number of panicle/hill

Number of panicle/hill is also a yield contributing factor. Panicle number/hill (number of effective tiller/plant) of the tested 109 local rice cultivars varied from 6 to14 where 20 HYVs were used as check. Topaboro of short grain and Kataribhog-232 of medium grain local rice cultivars had 14and 13 number of panicle/hill, which were higher than the HYVs. Among the HYVs, only BRRIdhan38 had 12 number of panicle/hill. Both Jol of long grain and Gojalgoria of medium grain local rice cultivars had 11 number of panicle/hill. Twenty three local rice cultivars had 10 number of panicle/hill as like as BR5, BR10, BR22, BRRI dhan32, BRRI dhan34, BRRI dhan37, BRRI dhan40 and BRRI dhan49. Forty six local rice cultivars had 9 number of panicle/hill as like as BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan33, BRRI dhan41, BRRI dhan44 and BRRI dhan46. Thirty local rice cultivars had 8 number of panicle/hill as like as BR4, BR11 and BRRI dhan39. Some cultivars including Motichak, Malagrosa, Minki, Murchmut and TK deep straw Tapl-773 had the second lowest position having 7 number of panicle/hill as well as Rahikhama which had the lowest one having 6 number of panicle/hill (Table-4.1.1a, Table-4.1.1b and Table-4.1.1c).

Among the 32 long grain local rice cultivars, Jol had the highest panicle number/hill (11) but TK deep straw Tapl-773 had the lowest panicle number/hill (7). Jol was only one cultivar, which had many panicle number//hill but rest of the cultivars which had intermediate panicle number/hill (Table-4.1.1a). Among the 48 medium grain local rice cultivars, Kataribhog-232 had the highest panicle number/hill (13) but Motichak had the lowest panicle number/hill (7). Two cultivarssuch as Kataribhog-232 and Gojalgoria had many panicle number/hill but rest of the cultivars had intermediate panicle number/hill (Table-4.1.1b). Among the 29 short grain local rice cultivars, Topaboro had the highest panicle number/hill (14) but Rahikhama had the lowest panicle number/hill (6). Topaboro was only one cultivar, which had many panicle number/hill but rest of the cultivars which had intermediate panicle number/hill (Table-4.1.1c). In long grain rice cultivars, local cultivars showed higher mean of panicle number/hill than that of HYVs. In medium and short grain rice cultivars, local cultivars showed lower mean of panicle number/hill than the HYVs (Figure-4.1.1a). Number of panicle/hill of the rice cultivar was classified as many panicle number/hill (>10), intermediate panicle number/hill (6-10) and few panicle number/hill(<6). In long, medium and short grain rice cultivars, 25%, 21% and 19% many panicle number/hill had at the level of >10. Accordingly, 75%, 79% and 81%intermediate panicle number/hillinlong, medium and short grain rice cultivarshadat the level of (6-10). But few panicle number/hill (<6) was not foundin long, medium and short grain rice cultivars (Figure-4.1.2b).

4.1.5 Panicle length

Panicle length is one of the important traits for yield contributing factors. There were different types of panicle length among the rice cultivars (Figure-4.1.5). Panicle length of the tested 109 local rice cultivars varied from 18 cm to 31 cm where 20 HYVs were used as check. In the local rice cultivars,Kanaibansi of long grain had the highest panicle length(31 cm) but Topaboro of short grain had the lowest panicle length (18 cm). Kalasaru and Rahikhama of short grain, Lalsoru of medium grain as well as TK deep straw Tapl-773 of long grain had 29 cm panicle length as like as BRRI dhan40 and BRRI dhan44. Some cultivars such as Kharmao, Hijli, Somondori, Dudhkalam, Joalbagh, Laxmikajol, Bariksail, Maloti, Kataribhog-1, Rajamora and Murchmut had 28 cm panicle length as same as BR11 and BRRI dhan41. Many cultivars such as Minki, Chinisagor, Michisail, Lalbinni, Baoijhaki, Bhorochalam, Sadamota, Hathazi, Malagrosa, Boradudhkalam, Gohatibinni, Dadkhani, Surjyamukhisangla, Jirakatari-1, Kalijira, Kataribhog-2, Shamrosh and Shithabhog had 27 cm panicle length as like as BR4, BR22, BR23 and BRRI dhan31. Most of the cultivars such as Khasha, Nariabochi, Jirakatari-2, Shata, Chunikanai, Putidepa, Kajalsail, Kalabinni-1, Athabinni, Kalabinni-2, Malsira, Uknimadhu, Ledabinni, Binniphul, Hatisail, Gojalgoria, Nunia, Lalmota, Binni-1, Neda, Redpiebald-219 and Kanaklata had 26 cm panicle length as like as BRRI dhan30, BRRI dhan32, BRRI dhan34 and BRRI dhan46. Most of the other cultivars such as Pajam, T.R.Aman, Lathamona, Joyna, Dudsail, Rangabinni, Gobcha, Pakhisail, Dholagachha, Pakibiroin, Tilokkajal, Bolonga, Nakchi, Khorma, Kalimanik, Chinigura, Jabsira, Tulsimala, Gurdoi, Sadajira Tapl-321, Betudhan and Tilkapur had 25 cm panicle length as like as BR25, BRRI dhan38 and BRRI dhan39. Some other cultivars such as Jhoshua, Cylindrical Tapi-629, Depa, Patnai-231, Ganjia, Nizersail, Paharisail, Sorukamina, Poushmoricha, Magoibalam, Nurior, Boylam and Chamara had 24 cm panicle length as same as BR10 and BRRI dhan49. Very few cultivars such as Kumragoir, Jhingasail-2, Binni-2, Najirsail and Lohasail had 23 cm panicle length as like as BRRI dhan37. Few cultivars such as Jingasail-1, Karailadhan, Kataribhog-232, Motichak, Molladigha, Dudsar Tapal-146, Jol, Harilaxmi and Kalisayta had 22 cm panicle length as same as BRRI dhan33. Two cultivars such as Changai and Hashfol both had 21 cm panicle length as same as BR5 (Table-4.1.1a, Table-4.1.1b and Table-4.1.1c).

Among the 32 long grain local rice cultivars, Kanaibansi had the highest panicle length (31 cm) but Jingasail-1, Molladigha, Dudsar Tapal-146, Jol, Harilaxmi and Karailadhan had the lowest panicle length (22 cm) (Table-4.1.1a). Among the 48 medium grain local rice cultivars, Lalsoru had the highest panicle length (29 cm) but both Hashfol and Changai had the lowest panicle length (21 cm) (Table-4.1.1b). Among the 29 short grain local rice cultivars,both Rahikhama and Kalasaru had the highest panicle length (29 cm) but Topaboro had the lowest panicle length (18 cm) (Table-4.1.1c). Short grain local rice cultivars showed the higher mean of panicle length than that of short grain HYVs. Whereas, long and medium grain local rice cultivars showed the lower mean of panicle length than long and medium grain HYVs (Figure-4.1.1b). Panicle length of the rice cultivars was classified as very long panicle length (>30 cm), long panicle length (25-30) cm, intermediate panicle length(21-24) cm and short panicle length (<21 cm). In the long grain rice cultivars, 3% very long panicle length had at the level of >30 cm. But very long panicle length was not found in medium and short grain rice cultivars.Accordingly, 61%, 61% and 71% long panicle length inlong, medium and short grain rice cultivars had at the level of (25-30) cm. Hence, 36%, 37% and 26% intermediate panicle length inlong, medium and short grain rice cultivars had at the level of (21-24) cm. In the medium and short grain rice cultivars,2% and 3% short panicle length had at the level of <21 cm (Figure-4.1.2b).

4.1.6 Plant height

Plant height is very important character for breeders to produce modern HYVs. The tested 109 local rice cultivars had a wide range of plant height starting from 86 cm to 205 cm where 20 HYVs were used as check. In the local rice cultivars, Pakhibiroin of medium grain had the highest plant height (205 cm) but Topaboro of short grain had the lowest plant height (86 cm). The local rice cultivars were usually taller than the HYVs (Table-4.1.1a, Table-4.1.1b and Table-4.1.1c). Tall plant height cultivars are classified as irrigated rice (111-150) cm, deep water rice (150-200) cm and floating rice >200 cm. Occasionally, deep water rice and floating rice cultivars require as desirable character to face the natural disaster such as flash flood, flood and stagnant water.

Among the 32 long grain local rice cultivars, Dudhkalam had the highest plant height (180 cm) but Harilaxmi had the lowest plant height (110 cm). All cultivars had tall plant height except Harilaxmi which had intermediate plant height. Harilaxmi had 110 cm plant height which was higher than the BRRI dhan39 but lower than the BRRI dhan41. Among them, six local cultivars had more than 160 cm plant height. They were Dudhkalam (180 cm), Gohatibinni (174 cm), Athabinni (172 cm), Kharmao (172 cm), Kanaibansi (170 cm) and Bhorochalam (165 cm). Some cultivars including Boradudhkalam, Hatisail, Joalbagh, Kalimanik, Khorma, Lathamona, Molladigha, Patnai-231, Redpiebald-219, Sadajira Tapl-321, Shata and TK deep straw Tapl-773 had the range of plant height of (150-160) cm. Other cultivars includingBinni-1, Binni-2, Cylindrical Tapi-629, Depa, Dudsar Tapal-146, Jingasail-1, Jol, Kalabinni-1, Karailadhan, Pakhisail, Shithabhog, Neda and T.R.Aman had the range of plant height of (120-150) cm (Table-4.1.1a).

Among the 48 medium grain local rice cultivars, Pakibiroin had the highest plant height (205 cm) but Magoibalam had the lowest plant height (126 cm). Here, all cultivars had tall plant height. Magoibalam had 126 cm plant height which was lower than the BR25 and BRRI dhan44 but higher than the BR4, BR10, BR11, BR22, BRRI dhan31, BRRI dhan32, BRRI dhan33, BRRI dhan37, BRRI dhan38, BRRI dhan40, BRRI dhan46 and BRRI dhan49. Among them,ten local cultivars had more than 160 cm plant height. These cultivars were Pakibiroin (205 cm), Dholagachha (193 cm), Lalsoru (180 cm), Rajamora (173 cm), Sadamota (168 cm), Joyna (166 cm), Putidepa (165 cm), Chamara (164 cm), Shamrosh (161 cm) and Tilokkajal (161 cm). Other cultivars including Bariksail, Dadkhani, Hashfol, Hijli, Kalabinni-2, Kataribhog-2, Lalbinni, Lalmota, Ledabinni, Nunia, Nakchi and Poushmoricha had the range of plant height of (150-160) cm. Most of the cultivars includingBolonga, Boylam, Changai, Ganjia, Gobcha, Gojalgoria, Hathazi, Jhingasail-2, Jhoshua, Kajalsail, Kalisayta, Kanaklata, Kataribhog-232, Kataribhog-1, Kumragoir, Lohasail, Maloti, Malsira, Motichak, Najirsail, Nizersail, Paharisail, Rangabinni and Tilkapur had the range of plant height of (131.8-150) cm (Table-4.1.1b).

Among the 29 short grain local rice cultivars, Betudhan had the highest plant height (193 cm) but Topaboro had the lowest plant height (86 cm). All cultivars had tall plant height except Topaboro which had short plant height. Topaboro had 86 cm plant height which was lower than the BR5 (120.2 cm) and BRRI dhan34(117.0 cm). Among them, seven local rice cultivars had more than 160 cm plant height. These cultivars were Betudhan (193 cm), Nurior (170 cm), Kalasaru (167 cm), Laxmikajol (162 cm), Binniphul (161 cm), Khasha

(161 cm) and Surjyamukhisangla (161 cm). Other cultivars includingUknimadhu, Chunikanai, Dudsail, Jirakatari-1, Jirakatari-2, Kalijira, Lalsaru and Michisail had the range of plant height of (150-160) cm. Most of the cultivars, Baoijhaki, Chinisagor, Chinigura, Gurdoi, Jabsira, Malagrosa, Minki, Murchmut, Nariabochi, Pajam, Rahikhama, Sorukamina and Tulsimala had the range of plant height of (139.6-150) cm (Table-4.1.1c).

Long, medium and short grain local rice cultivars showed higher mean of plant height than that of long, medium and short grain HYVs (Figure-4.1.1b). Plant height of the rice cultivar was classified as tall plant height (>110 cm), intermediate plant height (90-110) cm and short plant height (<90 cm). In long, medium and short grain rice cultivars, 94%, 94% and 97%tall plant height had at the level of >110 cm. Hence, 6% intermediate plant heightin both long and medium grain rice cultivarshad at the level of (90-110) cm as well as only 3% short plant height in short grain rice cultivar had at the level of (<90 cm)(Figure-4.1.2b). There were different plant heights among the rice cultivars (Figure-4.1.6).

4.1.7 Growth duration

Growth duration is one of the important character for breeders to produce modern HYVs. Growth duration of the tested 109 local rice cultivars varied from 106 days to 174 days where HYVs were used as check. Joyna of medium grain had the highest growth duration (174 days) but Gobcha also of medium grain had the lowest growth duration (106 days). The prominent short duration rice cultivarswere Gobcha (106 days), Rahikhama (107 days) and Kalisayta (110 days). Some important short duration rice cultivars such as Laxmikajol, Molladigha, Boylam and Sorukamina had the range of growth duration of (114-116) days. Chunikanai, Neda, Jol, Murchmut, Jirakatari-1 and Harilaxmi of some other short duration rice cultivarshad the range of growth duration of (118-120) days. The growth duration of these cultivars were close to the BRRI dhan33 (118 days). Some cultivars such as Dudsail, Kalasaru, Kanaklata, Kalabinni-2, Lalsaru, Chinigura, Rangabinni, Topaboro and Jirakatari-2 had the range of intermediate duration of (121-130) days as like as BRRI dhan32, BRRI dhan39 and BRRI dhan46 having the range of growth duration of (122-130) days. But rest of the cultivars had long duration. Cultivars such asKumragoir, Kataribhog-2, Ledabinni, Shamrosh, Surjyamukhisangla, Paharisail,Jhingasail-1, Maloti, Athabinni, Gohatibinni, Bolonga and Binni-1 had the range of growth duration of (131-134) days as like as BRRI dhan49 (134 days). Cultivars of Baoijhaki, Lohasail and Magoibalam had the growth duration of 135 days as same as BR25 and BRRI dhan34. Most of the cultivars such asLalbinni, Kalijira, Poushmoricha, Chinisagor, Tulsimala, Nurior, Dholagachha, Motichak, Nunia, Depa, Kataribhog-1, Kalabinni-2, Michisail, Bhorokalam, Pakhibirion, Binni-2, Kataribhog-232, Khasha and Uknimadhu had the range of growth duration of (136-140) days which was very close to BRRI dhan31, BRRI dhan37 and BRRI dhan38 having the growth duration of 140 days. Many cultivars such asBinniphul, T.R.Aman, Gojalgoria, Lalsoru, Somondori, Hathazi, Malagrosa, Khorma, Chamara, Rajamora, Nariabochi, Boradudhkalam, Ganjia, Jabsira, Dudhkalam, Bariksail and Malsira had the range of growth duration of (141-145) days which was very close to BR4, BR11, BRRI dhan30, BRRI dhan40 and BRRI dhan44 having the growth duration of 145 days. Some cultivars such asJoalbagh, Jhingasail-2, Nizersail, Tilokkajal, Hashfol, Dadkhani, Kalimanik, Shithabhog and Hatisail had the range of growth duration of (146-148) days as like as BRRI dhan41 having the growth duration of 148 days. Some other cultivars such as Pajam, Sadajira Tapl-321, Karailadhan, Cylindrical Tapi-629, Kanaibansi, Betudhan and Kharmao had the range of growth duration of (149-150) days as like as BR5, BR10, BR22 and BR23 having the growth duration of 150 days. Other cultivars such as Putidepa, Minki, Jhoshua, Lathamona, Lalmota, Najirsail, Hijli, Gurdoi, Kajalsail, TK deep straw Tapl-773, Dudsar Tapal-146, Tilkapur, Redpiebald-219, Nakchi,Patnai-231, Changai, Shata, Sadamota, Pakhisail and Joyna had the range of growth duration of (151-174) days which was obviously too much higher than the HYVs having the range of growth duration of (118-150) days (Table-4.1.1a, Table-4.1.1b and Table-4.1.1c).

Among the 32 long grain local rice cultivars, Pakhisail had the highest growth duration (171 days) but Molladigha had the lowest growth duration (115 days). Among them, 4 cultivars had short duration but rest of the cultivars had long duration. The prominent short duration cultivars were Molladigha (115 days), Neda (119 days), Jol (120 days) and Harilaximi (120 days) (Table-4.1.1a). Among the 48 medium grain local rice cultivars, Joyna had the highest growth duration (174 days) but Gobcha had the lowest growth duration (106 days). Among them, 3 cultivars had short duration but rest of the cultivars had medium and long duration. The prominent short duration cultivars were Gobcha (106 days), Kalisayta (110 days) and Boylam (115 days) (Table-4.1.1b). Among the 29 short grain local rice cultivars, Gurdoi had the highest growth duration (155 days) but Rahikhama had the lowest growth duration (107 days). Among them, 6 cultivars had short duration but rest of the cultivars had medium and long duration. The prominent short duration cultivars were Rahikhama (107 days), Laxmikajol (114 days), Sorukamina (116 days), Chunikanai (118 days), Murchmut (118 days) and Jirakatari-1 (120 days) (Table-4.1.1c).

In long grain rice cultivars, local cultivars showed higher mean of growth duration than that of HYVs. In medium grain rice cultivars, local cultivars showed slightly higher mean of growth duration than the HYVs. But in the short grain rice cultivars, local cultivars showed the lower mean of growth duration than the HYVs (Figure-4.1.1b). Growth duration of the rice cultivar was classified as long duration (>130 days), intermediate duration (121-130) days and short duration (<121 days). In long, medium and short grain rice cultivars, 86%, 86% and 65% long duration had at the level of >130 days. In long, medium and short grain rice cultivars, 3%, 8% and 16% intermediate duration had at the level of (121-130) days. In long, medium and short grain rice cultivars, 11%, 6% and 19%short duration had at the level of <121 days (Figure-4.1.2c**)**. There were different growth duration among the rice cultivars (Figure-4.1.7).

4.1.8 Percent of filled grains

Another trait of yield contributing factorsis percent of filled grains. Percent of filled grains of the tested 109 local rice cultivars varied from 39% to 98% where 20 HYVs were used as check. Shamrosh of medium grain rice cultivar had the highest percent of filled grains (98%) but Dholagachha also of medium grain had the lowest percent of filled grains (39%). Most of the prominent cultivars wereMolladigha, Sadamota, Changai, Gojalgoria,Dudsar Tapal-146, Maloti, Lalbinni, Gurdoi, Shithabhog, Pajam, Tilkapur, Lohasail, Boylam, Uknimadhu and Karailadhan. The range of percent of filled grains of these cultivars had(93-97)% which was higher than the HYVs. Few cultivars such asJoyna, Poushmoricha and Lathamona had 92% percent of filled grains which was similar to the BR23 (92%)but Athabinni, Minki and Somondori had lower percent of filled grains (90%). Some important cultivars such as Nakchi, Nizersail, Shata, Jhoshua and Bariksail had 89% percent of filled grains as same as BRRI dhan30, BRRI dhan44 and BRRI dhan49. Other prominent cultivars such as Chinisagor, Malagrosa, Kajalsail, Chinigura and Kanaklata had the percent of filled grains of 88% as same as BR10. Most of the important cultivars such as Depa, Bhorochalam, Putidepa, Jingasail-1, Khorma, Khasha, Baoijhaki, Nurior, Murchmut, Dadkhani, Hathazi, Chunikanai, Sorukamina, Dudhkalam, Binni-2, Najirsail, Binni-1, Ganjia, Bolonga and Betudhan had the percent of filled grains of 87%. Only one cultivar,Kharmao had the percent of filled grains of 82% as same as BR4 and BRRI dhan33. A small number of cultivars such as Pakibiroin, TK deep straw Tapl-773 and Hashfol had the percent of filled grains of 81% as same as BRRI dhan38butNeda and Jhingasail-2 had the percent of filled grains of 80% as same as BR11 and BRRI dhan38. Many cultivars such asHijli, Kanaibansi,Patnai-231, Jirakatari-1, Lalmota, Laxmikajol, Jirakatari-2, Kataribhog-232, Paharisail, Redpiebald-219, Boradudhkalam and Lalsoru had the range of percent of filled grains of (76-79)% which was higher than the BRRI dhan46. But Kataribhog-1 had 75% percent of filled grains as same as BRRI dhan46 as well as Malsira and Rangabinni both had the percent of filleds of 74% which was higher than the BR22 (73%). Few cultivars such asBinniphul, Jabsira, Ledabinni and Dudsail had the percent of filled grains of 72% as same as BR5 and BRRI dhan32. Cultivar of Kalabinni-2 had the percent of filled grains of 71% as same as BRRI dhan39 butbothT.R.Aman and Kataribhog-2 had the lower percent of filled grains (70%) than the BRRI dhan39. A small number of cultivars such as Hatisail, Pakhisail, Sadajira Tapl-321 andGohatibinni had the higher percent of filled grains (69%) than the BRRI dhan41 (68%). On the other hand, Michisail, Motichak and Kumragoir had the percent of filled grainsof (68%) as same as BRRI dhan41. Some prominent cultivars such as Harilaxmi, Kalabinni-1, Kalasaru, Tilokkajal, Rahikhama, Jol, Surjyamukhisangla, Tulsimala and Kalijira had the range of percent of filled grains of (60-67)% as like as BRRI dhan40, BRRI dhan34 and BRRI dhan31 having the range of percent of filled grains of (63-67)%. Cultivar of Joalbagh had 58% percent of filled grains as same as BR25. Some cultivars such asTopaboro, Magoibalam, Gobcha, Kalimanik,Cylindrical Tapi-629, Kalisayta, Nariabochi, Nunia, Rajamora and Chamara had the lower range of percent of filled grains of (47-57)% (Table-4.1.1a, Table-4.1.1b and Table-4.1.1c).

Among the 32 long grain local rice cultivars, Molladigha had the highest percent of filled grains (97%) but Kalimanik had the lowest percent of filled grains (54%) (Table-4.1.1a). Among the 48 medium grain local rice cultivars, Joyna had the highest percent of filled grains (98%) but Dholagachha had the lowest percent of filled grains (39%) (Table-4.1.1b).Among the 29 short grain local rice cultivars, Gurdoi had the highest percent of filled grains (95%) but Nariabochi had the lowest percent of filled grains (54%) (Table-4.1.1c). Medium and short grain local rice cultivars showed the higher mean of percent of filled grains than the medium and short grain HYVs. But long grain local rice cultivars showed the lower mean of percent of filled grains than that of long grain HYVs (Figure-4.1.1b). Percent of filled grains of the rice cultivar was classified as high percent of filled grains (>90%), intermediate percent of filled grains (50-90)% and low percent of filled grains (<50%). In long, medium and short grain rice cultivars, 19%, 19.4% and 13% high percent of filled grainshad at the level of >90%. Differently, 81%, 77.4% and 87%intermediate percent of filled grainsinlong, medium and short grain rice cultivars hadat the level of (50-90)%. In medium grain rice cultivars, 3.2% low percent of filled grainshad at the level of <50% (Figure-4.1.2c).

4.1.9 Correlation of agronomic characters

Pearson correlation coefficients for relationships had among various agronomic characters of different long grain rice cultivars. Thousand grain weight was significant and positively correlated with yield (r=0.418, p<0.05). Number of tiller/hill was negatively correlated with both yield and thousand grain weight. Number of panicle/hill was highly significant and positively correlated with number of tiller/hill (r=0.708, p<0.01). It was positively correlated with yield but negatively correlated with thousand grain weight. Panicle length was significant and positively correlated with yield (r=0.362, p<0.05). Plant height was significant and positively correlated with panicle length (r=0.394, p<0.05). Growth duration was significant and positively correlated with panicle length (r=0.360, p<0.05). Percent of filled grains was positively correlated with plant height and growth duration but other agronomic characters were negatively correlated (Table-4.1.2a).

Pearson correlation coefficients for relationships had among various agronomic characters of different medium grain rice cultivars. Thousand grain weight was positively correlated with yield. Number of tiller/hill was positively correlated with yield but negatively correlated with thousand grain weight. Number of panicle/hill was highly significant and positively correlated with number of tiller/hill (r=0.440, p<0.01). It was significant and positively correlated with yield (r=0.270, p<0.05) but negatively correlated with thousand grain weight. Panicle length was significant and positively correlated with yield (r=0.261, p<0.05). Plant height was highly significant and negatively correlated with yield(r=-0.412, p<0.01) as well as number of tiller/hill (r= -0.446, p<0.01). It was positively correlated with thousand grain weight and panicle length but significant and negatively correlated with number of panicle/hill (r= -0.285, p<0.05).Growth duration was positively correlated with all agronomic characters. Percent of filled grains was significant and positively correlated with yield (r=0.300, p<0.05) and growth duration (r=0.321, p<0.05) (Table-4.1.2b).

Pearson correlation coefficients for relationships had among various agronomic characters of different short grain rice cultivars. Thousand grain weight was positively correlated with yield. Number of tiller/hill was positively correlated with yield but negatively correlated with thousand grain weight. Number of panicle/hill was highly significant and positively correlated with number of tiller/hill (r=0.704, p<0.01). It was negatively correlated with yield and thousand grain weight. Panicle length was highly significant and negatively correlated with number of tiller/hill (r= -0.504, p<0.01) and number of panicle/hill(r= -0.627, p<0.01). Plant height was highly significant and positively correlated with panicle length (r=0.573, p<0.01). It was significant and negatively correlated with number of panicle/hill (r= -0.455, p<0.05). It was positively correlated with yield but negatively correlated with thousand grain weight and number of tiller/hill. Growth duration was positively correlated with yield and thousand grain weight. Percent of filled grains was significant and negatively correlated with number of panicle/hill (r= -0.361, p<0.05) (Table-4.1.2c).

4.1.10 Cluster analysis of agronomiccharacters

Agronomic traits (yield, thousand grain weight, total number of tiller/hill, total number of panicle/hill, panicle length, plant height, growth duration and percent of filled grains)of long, medium and short grain local rice cultivars based clustering provided 4 clusters: two clusters at level below 5, one cluster at level below 10 and another one cluster at level 25. Thousand grain weight, panicle length, number of panicle/hill and number of tiller/hill had very close relationship with yield in cluster-1 at level below 5 but percent of filled grains had also close relationship with yield in cluster-3at level below 10. Plant height and growth duration had close relationship with each other in cluster-2 at level below 5 but they had weak relationship with yield in cluster-4 at level 25 (Figure-4.1.3).

Similar agronomic traits of long, medium and short grain HYVs provided 4 clusters: two clusters at level below 5, one cluster at level below 10 and another one cluster at level 25. Thousand grain weight, panicle length, number of panicle/hill and number of tiller/hill had very close relationship with yield in cluster-1 at level below 5. Plant height and growth duration both had close relationship with each other in cluster-2 at level below 5. Not only percent of filled grains had close relationship with plant height and growth duration in cluster-3 at level below 10 but percent of filled grains also had very weak relationship with yield in cluster-4 at level 25 (Figure-4.1.4).

Table-4.1.1a: Mean performance of agronomic characters for 36 long grain rice cultivars

Sl.No.	Cultivars	Yield (t/ha)	Thousand grain Wt. (g)	No. of tiller/hill	No. of panicle/hill	Panicle length (cm)	Plant height (cm)	Growth duration (days)	Percent of filled grains (%)
1	Athabinni	3.5±0.40	27.2±0.38	10±0.84	9±4.66	26.2±0.84	172.0±7.76	134±0.45	90±0.83
2	Bhorochalam	3.3±0.50	26.2±1.78	10±0.84	9±2.33	27.0±1.41	165.0±4.12	140±0.72	87±1.33
3	Binni-1	2.7±0.39	25.8±0.30	14±0.71	10±4.36	25.8±1.10	143.8±8.07	134±2.00	84±0.67
4	Binni-2	2.1±0.37	24.1±1.40	13±1.00	9±1.30	22.6±0.89	146.4±3.85	140±1.04	84±1.25
5	Boradudhkalam	4.9±0.89	38.1±1.19	11±1.30	9±2.76	26.8±1.92	151.8±3.56	145±0.47	76±0.70
6	Cylindrical Tapi-629	3.4±0.35	31.7±0.90	10±1.14	8±1.55	24.4±0.55	141.4±5.73	150±0.45	55±0.85
7	Depa	2.9±0.35	30.9±1.11	15±0.84	9±2.40	24.2±1.30	126.6±3.71	139±0.84	87±1.46
8	Dudhkalam	5.2±0.62	37.2±0.17	13±0.84	9±2.74	28.0±2.24	179.6±13.16	145±1.00	84±1.30
9	Dudsar Tapal-146	2.7±0.60	26.7±0.22	12±1.14	10±1.67	21.8±1.30	137.0±7.42	155±0.74	96±0.65
10	Gohatibinni	4.0±0.74	26.6±0.85	10±0.84	8±4.60	26.8±1.48	174.4±9.04	134±0.49	69±0.25
11	Harilaxmi	4.0±0.83	25.6±0.68	11±1.52	9±3.41	21.7±1.79	110.2±6.26	120±0.92	67±1.05
12	Hatisail	3.7±0.50	30.8±1.22	12±3.21	9±2.22	26.0±0.00	159.0±2.24	148±1.53	69±1.00
13	Jingasail-1	1.3±0.22	24.4±0.47	14±0.45	9±1.60	22.4±2.79	139.8±5.60	133±0.66	87±0.78
14	Joalbagh	1.9±0.30	25.7±1.28	11±1.48	10±5.23	28.0±1.41	158.6±6.15	146±0.39	58±1.45
15	Jol	3.7±0.43	30.9±0.65	14±1.58	11±3.77	21.7±2.36	129.6±3.44	120±0.60	65±0.65
16	Kalabinni-1	3.7±0.65	32.9±0.12	10±1.30	8±2.65	26.2±0.84	149.2±9.47	140±0.34	67±1.00
17	Kalimanik	2.3±0.33	30.8±0.98	10±0.55	8±2.27	24.8±1.30	156.2±5.45	148±0.60	54±1.25
18	Kanaibansi	4.0±0.95	25.3±0.62	12±2.17	9±1.69	30.8±1.79	170.0±3.81	150±0.70	78±1.30
19	Karailadhan	3.5±0.39	25.2±0.60	11±1.30	10±2.02	22.4±2.07	130.2±3.90	150±0.44	93±1.10
20	Kharmao	3.6±0.73	26.0±0.96	11±0.89	9±1.47	28.4±1.52	171.8±5.31	150±2.78	82±0.50
21	Khorma	3.1±0.58	23.6±1.30	14±1.52	10±1.53	24.8±1.30	152.8±7.66	144±0.44	87±0.63
22	Lathamona	1.6±0.35	23.9±0.60	10±1.52	8±2.29	25.4±0.89	157.2±5.89	152±0.84	92±0.33
23	Molladigha	2.0±0.89	34.3±1.30	9±0.71	8±2.84	21.8±1.35	155.0±3.97	115±0.39	97±0.68
24	Neda	1.1±0.20	18.1±1.18	10±2.00	8±4.30	25.7±0.97	120.0±2.60	119±0.85	80±0.95
25	Pakhisail	3.8±0.75	30.0±0.50	13±1.14	10±2.22	25.2±1.30	127.6±4.72	171±0.67	69±0.95
26	Patnai-231	4.2±0.65	29.1±0.99	13±1.14	10±2.10	24.2±1.30	153.2±3.96	156±1.34	79±0.85
27	Redpiebald-219	3.2±0.78	24.4±0.60	12±1.14	9±1.38	25.6±0.89	157.0±4.12	155±1.01	76±0.78
28	Sadajira Tapl-321	2.9±0.40	26.0±0.20	13±1.14	9±1.56	24.6±0.55	150.8±6.06	150±0.38	69±0.35
29	Shata	4.0±0.61	27.4±0.20	9±1.22	8±4.23	26.2±1.79	157.0±2.35	160±1.53	89±0.80
30	Shithabhog	3.6±0.40	31.1±1.45	10±0.84	8±2.28	26.6±0.55	148.5±5.03	148±1.00	95±0.81
31	T.R.Aman	3.9±0.40	25.7±0.82	13±0.84	10±5.07	25.4±0.89	143.4±5.46	142±0.47	70±0.90
32	TK deep straw Tapl-773	3.2±0.55	26.6±0.50	9±0.89	7±1.74	29.0±1.00	153.4±5.37	155±0.61	81±0.40
33	BR23	4.1±0.58	28.2±0.48	10±1.92	9±4.38	27.4±1.34	120±5.86	150±1.46	92±0.75
34	BRRI dhan30	4.2±0.37	23.4±0.28	11±1.14	9±3.71	26.4±1.14	120±4.32	145±1.15	89±1.25
35	BRRI dhan39	4.5±0.35	25.1±0.89	10±0.84	8±2.02	25.4±1.52	106±2.30	122±1.00	71±0.75
36	BRRI dhan41	4.9±0.50	25.5±0.37	10±0.55	9±1.94	28.0±1.87	115±4.64	148±0.40	68±0.70
Range		**1.1-5.2**	**18.1-38.1**	**9.0-15**	**7.0-11**	**21.7-30.8**	**106-179.6**	**115-171**	**54-97**
Mean±SD		**3.4±0.99**	**27.6±4.04**	**11±1.68**	**9±0.86**	**25.5±2.21**	**145.8±18.96**	**143±12.44**	**79±11.81**
CV%		**30**	**15**	**15**	**10**	**9**	**13**	**9**	**15**
SE (Standard error)		**0.299**	**0.392**	**1.008**	**1.3867**	**0.9305**	**2.18**	**0.375**	**0.182**
LSD (0.05)		**0.8436**	**1.106**	**2.846**	**3.9109**	**2.624**	**6.13**	**1.057**	**0.514**

Table-4.1.1b: Mean performance of agronomic characters for 62 medium grain rice cultivars

Sl.No.	Cultivars	Yield (t/ha)	Thousand grain Wt. (g)	No. of tiller/hill	No. of panicle/hill	Panicle length (cm)	Plant height (cm)	Growth duration (days)	Percent of filled grains (%)
1	Bariksail	3.6±0.56	20.1±0.71	10±1.14	8±4.13	27.8±1.30	158.8±9.15	145±1.08	89±0.73
2	Bolonga	2.1±0.30	20.7±0.28	11±0.84	8±2.46	24.9±2.33	144.4±6.61	134±1.14	83±0.85
3	Boylam	1.2±0.22	25.2±0.68	12±1.58	8±2.27	23.8±1.30	140.0±4.39	115±2.00	94±0.50
4	Chamara	1.7±0.29	24.8±0.57	11±0.71	9±3.38	23.6±1.95	163.8±9.18	144±1.00	47±1.25
5	Changai	3.3±0.55	26.1±0.92	13±1.92	10±1.92	21.2±0.84	133.4±1.34	160±1.53	96±0.86
6	Dadkhani	2.0±0.42	16.5±0.68	11±1.22	8±2.27	26.8±1.30	155.0±5.00	147±2.52	86±0.86
7	Dholagachha	2.9±0.20	24.4±1.03	10±1.14	8±3.63	25.2±1.10	193.2±6.76	139±0.51	39±0.99
8	Ganjia	4.3±0.35	17.1±0.35	11±0.55	10±2.73	24.2±1.04	148.2±4.32	145±0.50	84±0.55
9	Gobcha	2.2±0.29	25.5±0.73	11±0.71	9±2.40	25.2±1.79	143.3±4.06	106±1.00	55±1.30
10	Gojalgoria	4.0±0.66	23.6±0.33	12±0.45	11±2.68	25.9±1.95	148.5±7.91	142±1.73	96±0.55
11	Hashfol	3.4±0.40	25.0±0.95	11±0.84	9±2.12	20.8±1.64	159.0±5.92	146±0.88	81±0.25
12	Hathazi	3.1±0.35	29.1±0.83	11±1.00	8±2.58	27.0±0.71	147.0±5.87	143±0.65	86±0.85
13	Hijli	3.8±0.83	17.1±1.03	10±0.84	9±1.74	28.4±0.55	153.0±4.92	155±0.47	79±1.65
14	Jhingasail-2	3.3±0.35	30.0±0.90	13±3.03	8±4.02	23.1±2.61	144.2±10.57	146±0.58	80±0.45
15	Jhoshua	4.2±0.30	23.7±0.33	14±1.14	9±1.60	24.4±2.19	136.8±4.21	152±0.57	89±0.78
16	Joyna	2.1±0.10	26.1±0.65	10±1.14	8±3.74	25.3±0.84	166.4±5.77	174±1.53	92±1.50
17	Kajalsail	4.2±0.61	31.2±0.93	14±0.84	10±1.78	26.2±0.84	145.8±3.35	155±0.57	88±1.00
18	Kalabinni-2	2.0±0.24	21.0±0.95	14±1.95	9±1.43	26.0±2.67	156.2±3.70	124±1.00	71±0.45
19	Kalisayta	1.5±0.30	25.7±0.48	12±0.55	8.0±2.27	21.5±1.50	140.0±4.32	110±1.23	55±0.80
20	Kanaklata	3.5±0.83	17.1±0.83	11±0.89	9±4.12	25.5±1.73	146.6±8.02	124±0.70	88±0.46
21	Kataribhog-232	1.9±0.38	14.7±0.43	16±1.92	13±2.26	22.2±0.45	139.0±2.59	140±1.69	77±0.95
22	Kataribhog-1	2.6±0.35	15.9±0.99	15±0.84	8±2.18	27.8±0.45	147.8±2.49	139±1.05	75±2.99
23	Kataribhog-2	2.2±0.60	14.9±0.80	10±1.10	9±3.91	26.6±2.07	152.2±3.03	131±1.00	70±0.65
24	Kumragoir	3.2±0.39	26.5±0.44	12±1.52	10±1.72	23.4±2.07	135.0±5.24	131±0.90	68±0.55
25	Lalbinni	3.8±0.47	23.5±0.45	12±1.52	10±2.14	27.2±1.30	156.2±5.89	136±0.65	95±1.03
26	Lalmota	2.5±0.34	30.5±0.73	11±1.52	9±4.07	25.8±1.30	152.0±4.53	153±0.91	78±1.05
27	Lalsoru	3.8±0.55	14.7±0.43	10±0.89	8±2.84	29.3±2.05	180.2±8.67	142±2.52	76±0.65
28	Ledabinni	2.6±0.44	24.8±0.26	11±0.84	8±4.70	26.0±1.73	151.2±5.54	131±1.28	72±0.95
29	Lohasail	3.6±0.35	25.4±0.94	10±1.10	8±1.83	22.5±0.79	132.3±4.55	135±0.62	94±0.60
30	Magoibalam	0.9±0.04	22.3±1.35	11±1.14	9±3.71	23.9±2.41	126.0±5.83	135±0.70	56±0.75
31	Maloti	3.3±0.55	21.2±0.41	11±0.84	8±1.65	27.8±1.10	147.6±6.11	133±0.78	95±1.51
32	Malsira	3.5±0.38	21.3±0.78	12±0.84	10±2.41	26.0±2.35	131.8±4.02	145±1.32	74±1.00
33	Motichak	1.6±0.23	27.4±0.48	9±0.89	7±2.27	22.1±1.24	145.0±3.30	139±0.53	68±1.23
34	Najirsail	2.7±0.28	18.8±0.68	17±1.14	10±4.79	22.5±0.89	133.6±6.80	153±1.50	84±1.00
35	Nakchi	3.7±0.36	31.7±1.21	11±1.30	9±1.67	24.8±2.31	150.6±8.38	159±1.00	89±1.20
36	Nizersail	3.2±0.35	17.4±1.10	12±0.89	9±4.64	24.2±0.45	140.8±5.02	146±0.72	89±0.85

Sl.No.	Cultivars	Yield (t/ha)	Thousand grain Wt. (g)	No. of tiller/hill	No. of panicle/hill	Panicle length (cm)	Plant height (cm)	Growth duration (days)	Percent of filled grains (%)
37	Nunia	2.0±0.35	19.2±0.67	14±1.10	9±1.51	25.8±2.49	159.0±10.49	139±0.76	52±0.55
38	Paharisail	2.3±0.43	22.3±0.98	14±0.55	9±1.46	24.1±3.25	139.6±6.23	133±1.17	77±0.46
39	Pakibiroin	2.8±0.45	27.7±1.20	11±1.14	9±3.60	25.0±1.22	205.2±12.28	140±0.92	81±0.75
40	Poushmoricha	3.4±0.53	23.3±0.58	10±1.00	8±3.63	24.0±0.71	154.6±10.41	138±0.98	92±0.35
41	Putidepa	3.5±0.35	27.1±0.83	12±0.89	10±2.42	26.2±1.10	164.8±5.22	151±0.66	87±0.94
42	Rajamora	1.3±0.45	31.3±0.88	10±0.45	8±4.37	27.6±1.34	173.0±3.32	144±1.27	51±0.95
43	Rangabinni	2.8±0.15	22.4±0.58	11±1.22	9±1.71	25.2±2.05	138.6±6.43	127±1.84	74±0.30
44	Sadamota	2.4±0.45	31.4±0.68	11±0.84	9±1.91	27.0±1.00	168.0±6.78	161±0.90	96±2.94
45	Shamrosh	2.8±0.45	25.0±0.29	14±1.30	9±2.24	26.6±1.56	161.3±4.09	132±0.31	98±0.60
46	Somondori	3.2±0.42	21.1±0.83	12±0.71	10±2.33	28.2±2.49	159.2±10.71	143±0.46	90±0.35
47	Tilkapur	2.9±0.40	23.5±0.78	14±1.34	10±1.76	24.5±1.95	147.4±6.54	155±0.75	94±0.65
48	Tilokkajal	4.5±0.65	30.0±1.48	10±1.34	8±5.10	25.0±0.71	161.4±13.39	146±0.75	65±1.60
49	BR4	4.5±0.44	20.1±0.55	11±0.84	8±1.67	27.2±1.92	125.0±4.09	145±1.89	82±0.65
50	BR10	4.6±0.38	20.8±0.73	13±2.30	10±1.43	24.4±1.34	115.0±1.22	150±1.59	88±1.00
51	BR11	3.7±0.29	21.9±0.78	11±1.52	8±1.32	28.3±1.99	115.2±3.11	145±0.58	80±1.75
52	BR22	4.0±0.70	20.1±1.76	12±1.30	10±1.25	26.8±1.10	125.0±4.02	150±0.55	73±1.05
53	BR25	4.4±0.35	20.4±0.24	12±0.84	9±3.50	25.3±1.99	138.0±7.60	135±1.17	58±1.41
54	BRRI dhan31	4.3±0.93	27.1±0.76	12±1.34	9±3.74	26.9±2.41	115.0±3.44	140±0.55	64±1.00
55	BRRI dhan32	4.4±0.25	22.2±0.82	14±2.07	10±3.73	25.9±1.52	120.0±2.66	130±0.51	72±1.25
56	BRRI dhan33	3.3±0.36	24.6±1.07	12±0.55	9±1.91	22.3±2.22	100.0±4.15	118±1.00	82±1.10
57	BRRI dhan37	3.3±0.30	22.1±0.41	11±0.84	10±1.88	23.0±1.58	125.0±3.97	140±1.53	80±0.81
58	BRRI dhan38	4.0±0.32	20.0±0.45	14±1.64	12±1.90	25.0±1.58	122.6±6.43	140±0.83	81±1.06
59	BRRI dhan40	4.8±0.50	29.3±0.68	11±1.14	10±1.84	28.8±2.17	110.0±1.79	145±0.89	67±1.20
60	BRRI dhan44	4.7±0.28	29.9±0.56	11±0.89	9±2.01	29.0±2.35	130.0±5.77	145±1.79	89±0.58
61	BRRI dhan46	4.7±0.46	26.2±0.58	11±1.10	9±1.98	25.8±1.10	105.0±2.00	124±1.27	75±0.85
62	BRRI dhan49	5.6±0.28	20.3±0.46	14±1.67	10±2.12	24.4±2.30	100.0±3.85	134±0.65	89±1.35
Range		**0.9-5.6**	**17.4-31.7**	**9.0-17**	**7.0-13**	**20.8-29.3**	**100-205.2**	**106-174**	**39-98**
Mean±SD		**3.2±1.03**	**23.2±4.75**	**12±1.63**	**9±1.05**	**25.3±2.01**	**143.9±20.30**	**140±12.17**	**79±13.68**
CV%		**32**	**20**	**14**	**12**	**8**	**14**	**9**	**17**
SE (Standard error)		**0.2210**	**0.2068**	**1.077**	**0.8064**	**0.8948**	**2.8629**	**0.3957**	**0.3454**
LSD (0.05)		**0.6187**	**0.5789**	**3.015**	**2.257**	**2.5049**	**8.0141**	**1.1077**	**0.9670**

Table-4.1.1c: Mean performance of agronomic characters for 31 short grain rice cultivars

Sl.No.	Cultivars	Yield (t/ha)	Thousand grain Wt. (g)	No. of tiller/hill	No. of panicle/hill	Panicle length (cm)	Plant height (cm)	Growth duration (days)	Percent of filled grains (%)
1	Baoijhaki	1.8±0.61	17.0±1.02	11±1.14	9±5.50	27.2±0.84	148.4±5.68	135±0.43	86±1.32
2	Betudhan	3.6±3.21	25.9±0.88	13±0.71	8±1.56	24.6±0.55	193.2±6.87	150±2.38	83±0.68
3	Binniphul	3.1±0.79	12.9±0.22	10±0.55	9±1.30	26.0±1.58	161.0±8.72	141±0.64	73±0.87
4	Chinisagor	3.1±0.72	12.7±0.68	12±0.84	8±2.76	27.4±0.55	149.2±4.15	138±1.10	88±1.37
5	Chinigura	2.7±0.64	12.5±0.45	14±2.30	9±1.72	24.7±1.40	150.4±8.59	125±1.12	88±1.00
6	Chunikanai	2.9±0.55	11.2±0.58	12±0.89	9±3.70	26.2±1.30	155.6±3.97	118±1.00	86±0.85
7	Dudsail	3.9±0.18	15.2±0.62	13±1.58	9±5.69	25.2±2.68	160.4±6.99	121±1.01	72±0.86
8	Gurdoi	3.4±0.56	14.9±0.85	13±1.22	9±1.81	24.6±0.89	140.2±4.82	155±0.54	95±1.01
9	Jabsira	2.8±0.75	22.3±0.78	11±0.89	9±2.46	24.6±1.95	144.6±6.47	145±0.78	72±0.95
10	Jirakatari-1	2.5±0.15	10.3±0.36	13±1.14	10±4.30	26.8±0.45	157.4±5.41	120±0.84	78±1.36
11	Jirakatari-2	1.6±0.40	12.8±0.41	11±1.82	9±3.79	26.3±1.10	151.8±6.50	130±0.25	78±0.85
12	Kalasaru	2.4±0.28	12.6±0.22	12±1.34	9±2.68	29.2±2.17	167.2±5.45	122±1.00	66±1.10
13	Kalijira	2.3±0.30	10.9±0.86	11±0.89	9±4.77	26.7±0.84	150.6±4.04	137±0.76	60±0.85
14	Khasha	3.0±0.40	11.2±0.45	11±1.14	10±1.65	26.4±2.41	161.2±5.17	140±2.32	87±0.47
15	Lalsaru	3.1±0.61	12.4±0.35	14±0.71	10±2.56	25.6±1.82	153.6±6.50	125±1.10	57±0.45
16	Laxmikajol	1.8±0.15	10.3±0.47	13±1.58	10±2.10	28.0±0.71	162.0±6.52	114±0.33	78±0.91
17	Malagrosa	2.7±1.24	13.4±0.29	10±0.45	7±2.37	26.8±2.11	141.9±7.21	143±1.58	88±1.30
18	Michisail	2.9±0.35	11.4±0.68	11±0.55	9±2.46	27.2±1.30	155.4±5.81	140±0.54	68±1.45
19	Minki	2.0±0.60	26.2±0.58	12±1.82	7±2.54	27.4±0.89	145.4±4.39	151±1.02	90±0.80
20	Murchmut	2.3±0.61	21.7±0.33	9±0.84	7±3.65	27.6±0.55	146.4±2.61	118±0.61	86±0.95
21	Nariabochi	3.3±0.48	24.7±0.67	12±1.10	9±2.67	26.4±0.89	147.6±3.85	144±1.52	54±0.50
22	Nurior	2.0±0.20	20.8±0.18	11±1.64	9±1.65	23.9±1.95	169.6±15.98	139±0.51	86±1.05
23	Pajam	3.4±3.4	17.1±0.84	10±1.92	8±4.75	25.4±1.34	139.6±4.98	149±0.95	94±0.90
24	Rahikhama	1.5±0.30	20.5±0.46	10±0.45	6±3.73	29.0±3.00	150.0±4.90	107±1.01	65±0.96
25	Sorukamina	3.3±0.71	10.9±0.74	10±0.84	8±3.73	24.0±1.00	148.2±5.02	116±1.09	85±0.85
26	Surjyamukhisangla	1.7±0.20	10.5±0.57	13±1.79	9±3.88	26.8±1.30	160.6±5.55	132±1.16	64±1.20
27	Topaboro	2.1±0.20	21.7±0.29	17±2.28	14±4.68	18.0±0.76	86.4±4.04	128±1.75	57±0.45
28	Tulsimala	3.4±0.52	18.1±0.51	10±0.71	9±1.74	24.6±1.67	143.8±4.55	139±0.41	63±0.56
29	Uknimadhu	2.0±0.61	10.8±0.23	13±0.84	10±1.63	26.0±2.35	155.8±6.46	140±2.47	93±1.30
30	BR5	3.4±0.56	12.2±0.43	13±1.48	10±1.58	20.8±0.76	120.2±6.80	150±0.89	72±0.95
31	BRRI dhan34	2.3±0.90	10.8±0.79	11±1.14	10±1.90	25.8±2.49	117.0±3.97	135±0.76	63±1.01
Range		**1.5-3.9**	**10.3-26.2**	**9.0-17.0**	**6.0-14.0**	**18.0-29.2**	**86.4-193.2**	**107-155**	**54-95**
Mean±SD		**2.7±0.75**	**15.4±5.09**	**12±1.64**	**9±1.38**	**25.8±2.19**	**149.5±18.0**	**134±12.51**	**76.6±12.3**
CV%		**28**	**33**	**14**	**15**	**9**	**12**	**9**	**16**
SE (Standard error)		**0.2470**	**0.1516**	**1.0025**	**0.8586**	**0.7651**	**1.525**	**0.4203**	**0.1609**
LSD (0.05)		**0.6988**	**0.4288**	**2.8356**	**2.4287**	**2.1642**	**4.3142**	**1.1889**	**0.455**

Table-4.1.2a: The Pearson correlation coefficient for agronomic characteristics on the basis of different long grain rice cultivars

Correlations

Parameters	**Yield (t/h)**	**Thousand grain weight (g)**	**Number of tiller/hill**	**Number of panicle/hill**	**Panicle length (cm)**	**Plant height (cm)**	**Growth duration (days)**
Yield (t/h)	1						
Thousand grain weight (g)	.418*	1					
Number of tiller/hill	-.061	-.007	1				
Number of panicle/hill	.110	-.051	.708**	1			
Panicle length (cm)	.362*	-.001	-.306	-.290	1		
Plant height (cm)	-.036	.268	-.061	-.130	.394*	1	
Growth duration (days)	.219	.079	.022	.070	.360*	.254	1
Percent of filled grains (%)	-.140	-.127	-.016	-.021	-.089	.069	.012

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table-4.1.2b: The Pearson correlation coefficient for agronomic characteristics on the basis of different medium grain rice cultivars

Correlations

Parameters	**Yield (t/h)**	**Thousand grain weight (g)**	**Number of tiller/hill**	**Number of panicle/hill**	**Panicle length (cm)**	**Plant height (cm)**	**Growth duration (days)**
Yield (t/h)	1						
Thousand grain weight (g)	.007	1					
Number of tiller/hill	.063	-.230	1				
Number of panicle/hill	.270*	-.220	.440**	1			
Panicle length (cm)	.261*	-.034	-.150	-.139	1		
Plant height (cm)	-.412**	.114	-.446**	-.285*	.155	1	
Growth duration (days)	.208	.152	.004	.123	.149	.211	1
Percent of filled grains (%)	.300*	-.027	.101	.154	.044	-.093	.321*

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table-4.1.2c: The Pearson correlation coefficient for agronomic characteristics on the basis of different short grain rice cultivars

Correlations

Parameter	Yield (t/h)	Thousand grain weight (g)	Number of tiller/hill	Number of panicle/hill	Panicle length (cm)	Plant height (cm)	Growth duration (days)
Yield (t/h)	1						
Thousand grain weight (g)	.024	1					
Number of tiller/hill	.031	-.030	1				
Number of panicle/hill	-.020	-.232	.704**	1			
Panicle length (cm)	-.279	-.169	-.504**	-.627**	1		
Plant height (cm)	.098	-.036	-.248	-.455*	.573**	1	
Growth duration (days)	.263	.283	-.033	.000	-.265	-.076	1
Percent of filled grains (%)	.030	-.031	-.205	-.361*	.117	.246	.216

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

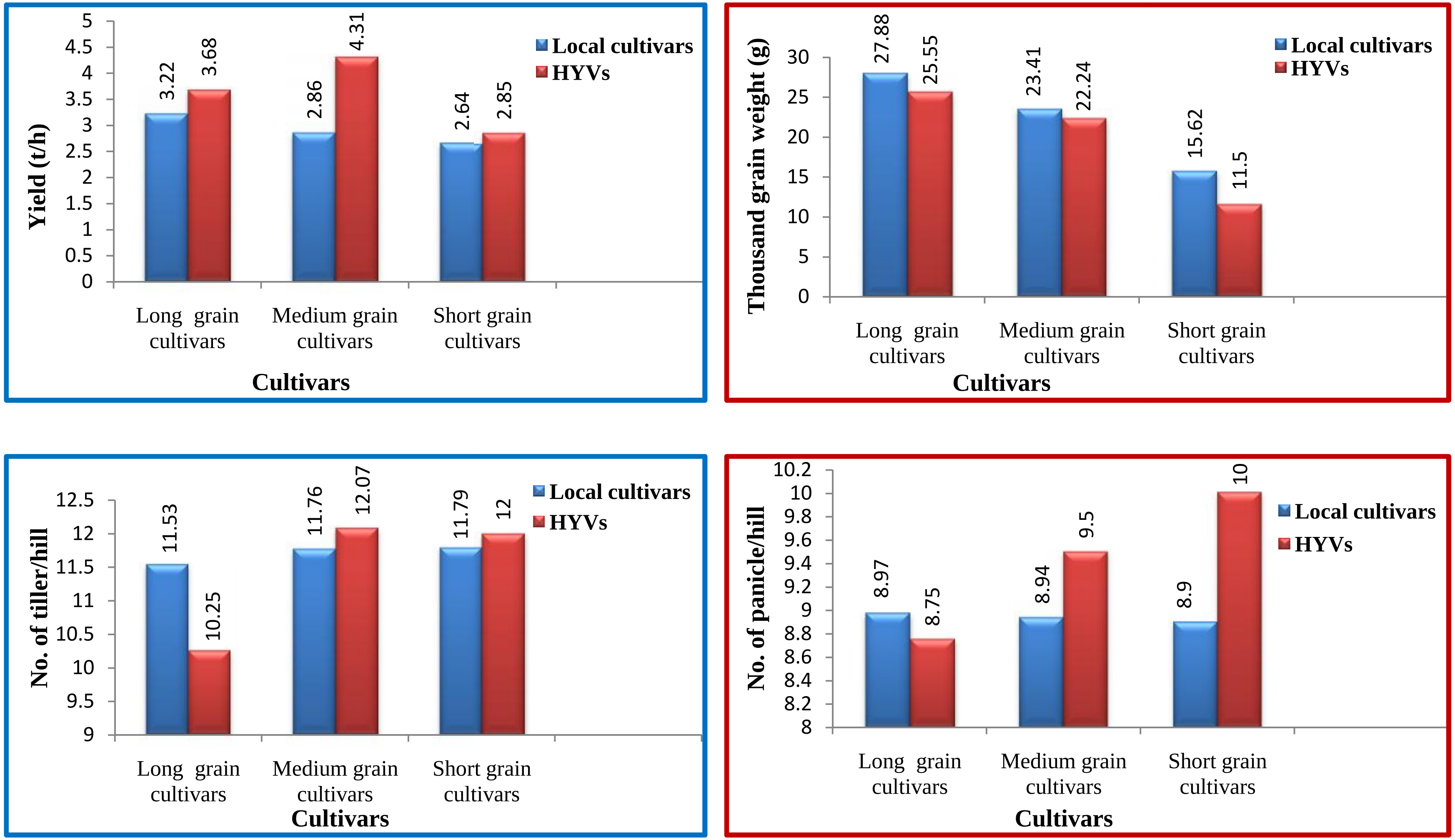

Figure-4.1.1a: Comparison of yield, thousand grain weight, number of tiller/hill and number of panicle/hillfor different local rice cultivars andHYVs

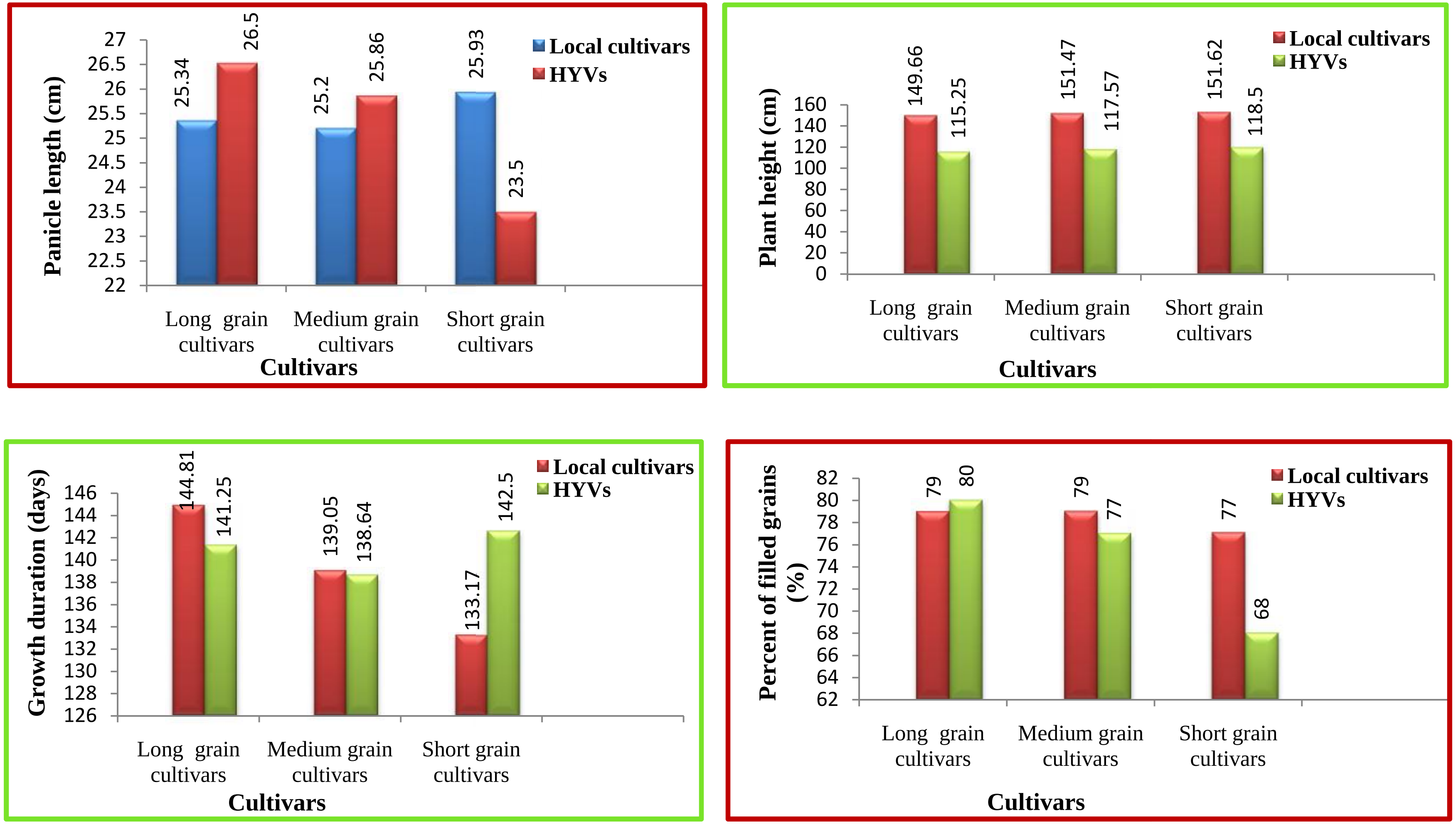

Figure-4.1.1b: Comparison of panicle length, plant height, growth duration and percent of filled grains for different local rice cultivars andHYVs

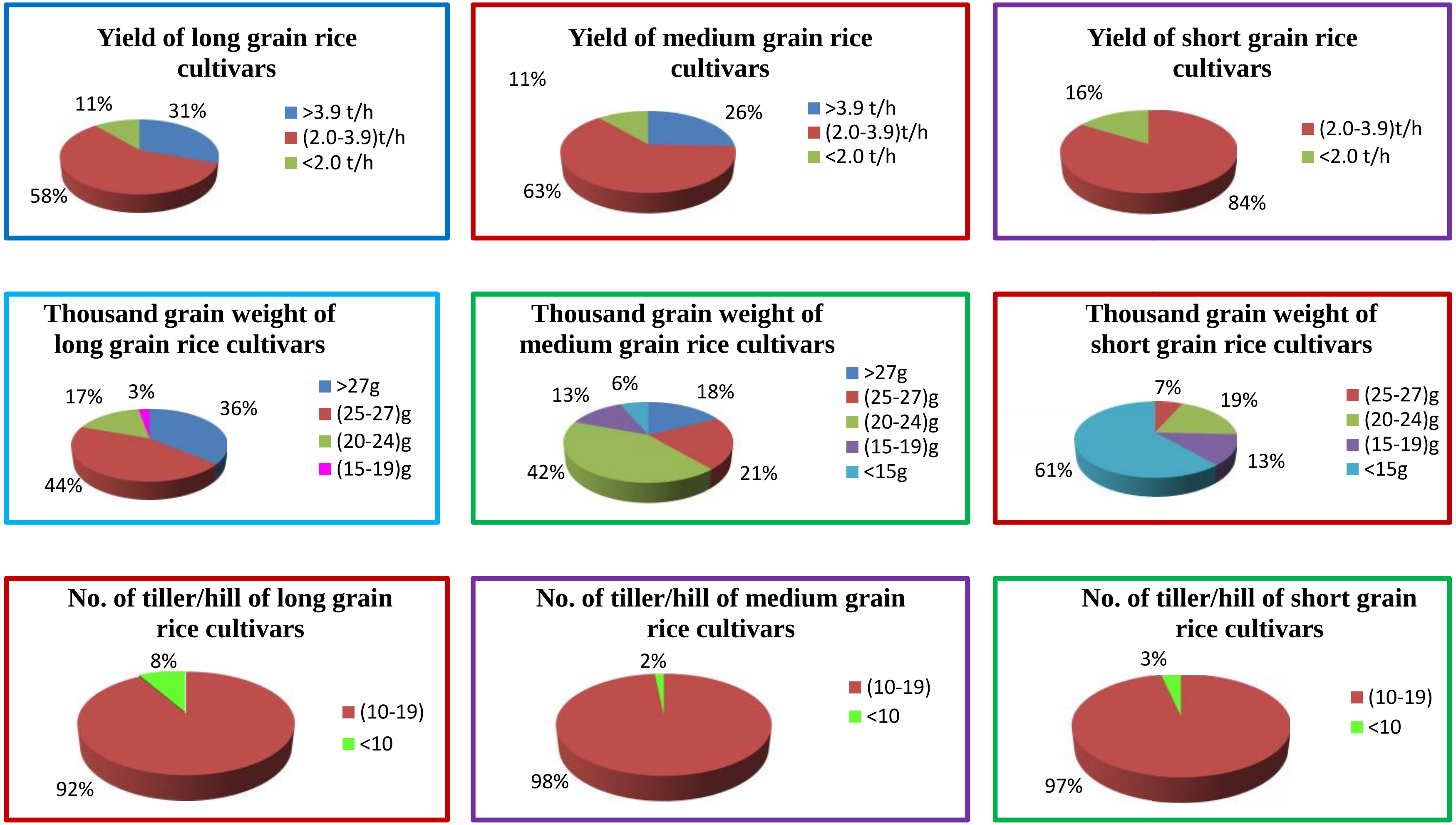

Figure-4.1.2a: Frequency distribution of yield, thousand grain weight and number of tiller/hill for long, medium and short grain rice cultivars

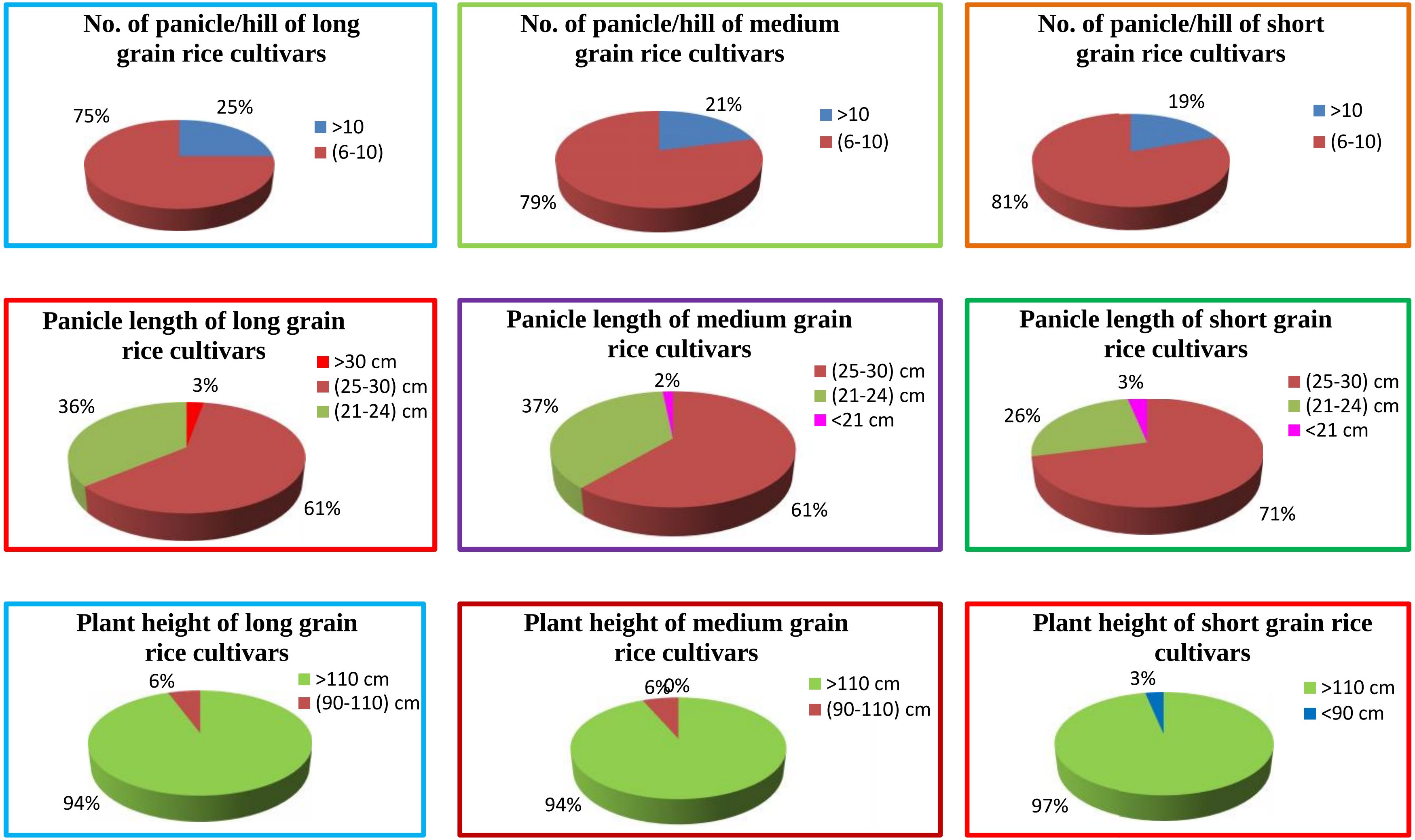

Figure-4.1.2b: Frequency distribution ofnumber of panicle/hill, panicle lengthand plant height for long, medium and short grain rice cultivars

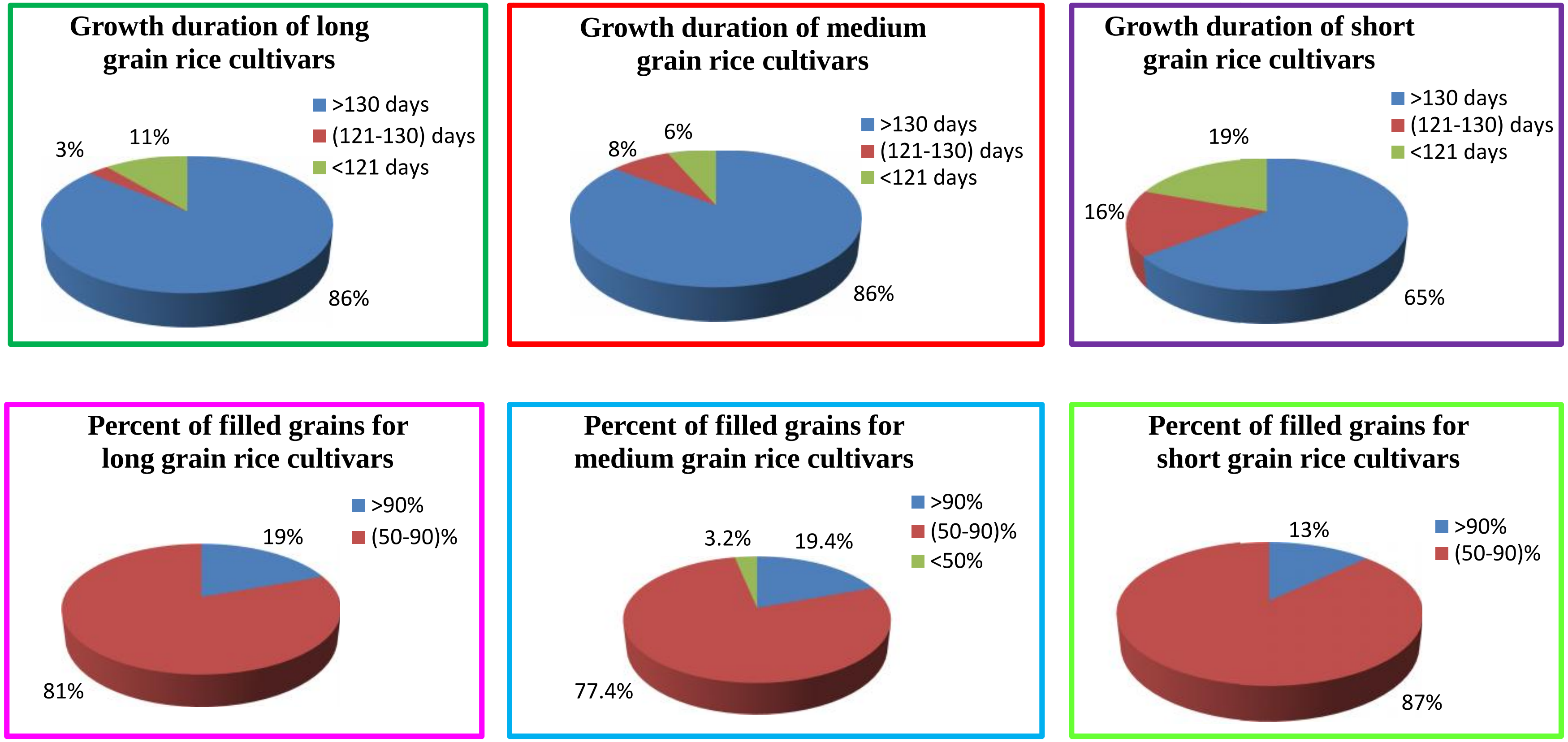

Figure-4.1.2c: Frequency distribution ofgrowth duration and percent of filled grains for long, medium and short grain rice cultivars

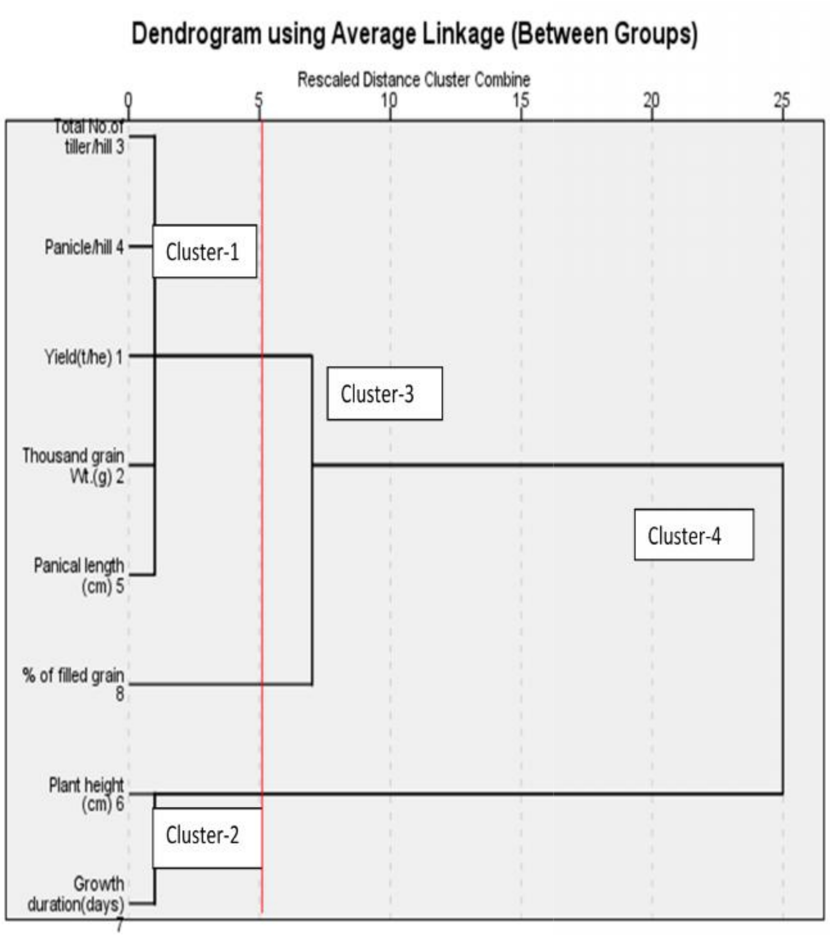

Figure-4.1.3: Dendrogram of agronomiccharacters on the basis of all local cultivars

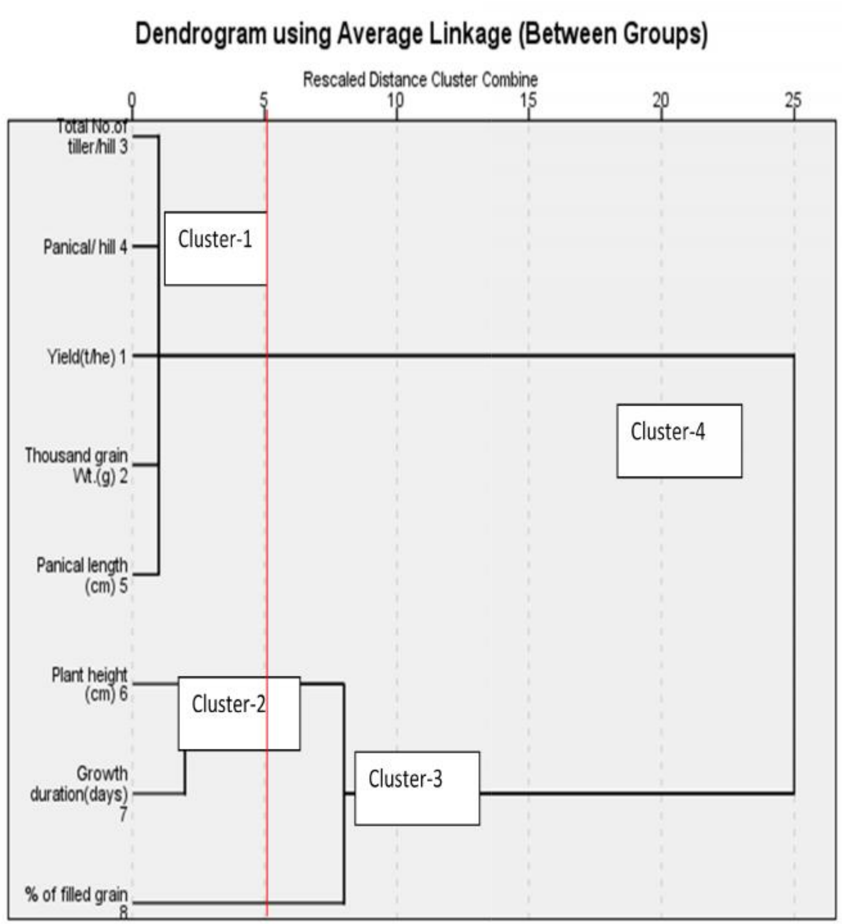

Figure-4.1.4: Dendrogram of agronomic characters on the basis of all HYVs

Figure-4.1.5: Different panicle length of long, medium and short grain local rice cultivars

Figure-4.1.6: Different plant height of local rice cultivars

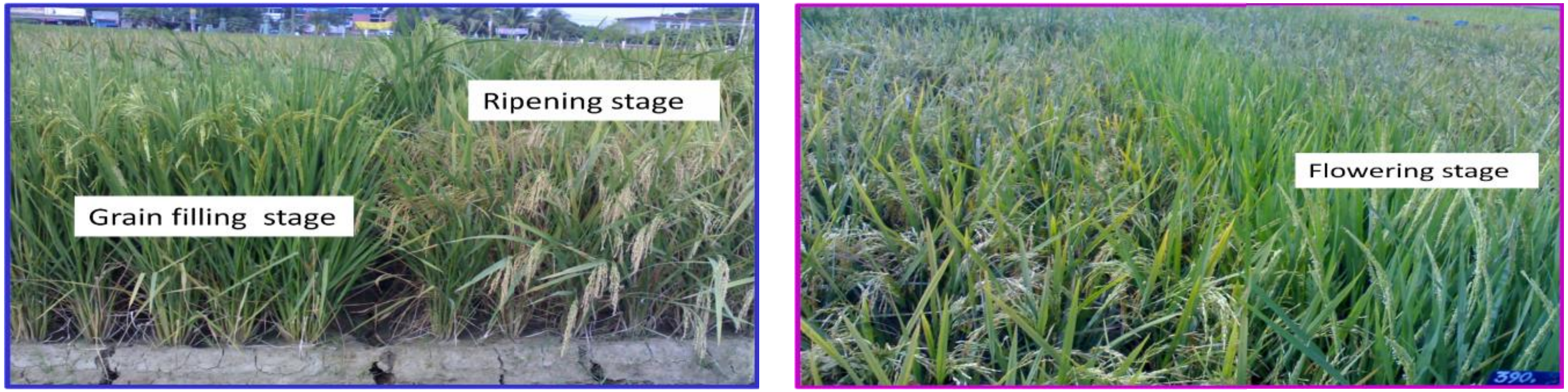

Figure-4.1.7:Different growth duration of local rice cultivars at the same day

4.2: Evaluation of morphological and physical properties for long, medium and short grain rice cultivars

4.2 Morphological and physical properties

In total, 129 rice cultivars including109local rice cultivars and 20HYVs of rice have been evaluated by morphological and physical traits such aspanicle threshability, panicle type, awn status, hull color, pericarp color, grain size and shape, chalkiness as well as appearance.

4.2.1 Panicle threshability

Panicle threshability is one of the post-harvest operations. Panicle threshing is the process of separating paddy from straw and threshability is the capacity of paddy to separate it from the straw.Out of 129 rice cultivars, 56 had desirable intermediate panicle threshability but others had difficult and easy panicle threshability. Long grain rice cultivars such as Athabinni, Binni-1, Boradudhkalam, Gohatibinni, Jol, Kalabinni-1, Kalimanik, Karailadhan, Khorma, Lathamona, Neda, Shata, Shithabhog, T.R.Aman, TK deep straw Tapl-773, BRRI dhan39andBRRI dhan41had intermediate panicle threshability but others had difficult panicle threshability. Easy panicle threshabilityhad not been found at all in long grain rice cultivars (Table-4.2.1a). Most of the tested medium grain rice cultivars had difficult and intermediate panicle threshability. Medium grain rice cultivars such as Bolonga, Boylam, Dadkhani, Ganjia, Gobcha, Gojalgoria, Hijli, Joyna, Kalabinni-2, Kalisayta, Kataribhog-232, Kataribhog-1, Kataribhog-2, Lalbinni, Lalmota, Ledabinni, Motichak, Najirsail, Paharisail, BRRI dhan44, BRRI dhan46 and BRRI dhan49 had intermediate panicle threshability but others had difficult and easy panicle threshability. Among them Kumragoir, Sadamota, Chamara, Tilkapur and Dholagachha had easy panicle threshability (Table-4.2.1b). Most of the tested short grain rice cultivars had difficult and intermediate panicle threshability. Short grain rice cultivars such as Baoijhaki, Binniphul, Chinisagor, Chinigura, Chunikanai, Jirakatari-1, Jirakatari-2, Kalasaru, Laxmikajol, Michisail, Murchmut, Nariabochi, Pajam, Sorukamina, Surjyamukhisangla, Tulsimala and Uknimadhu had intermediate panicle threshability but others had difficult and easy panicle threshability. Only, Jabsira had easy panicle threshability in the short grain rice cultivars (Table-4.2.1c). In the long grain rice cultivars, 53% had difficult and 47% had intermediate panicle threshability. In the medium grain rice cultivars, 58% had difficult; 32% had intermediate and 10% had easy panicle threshability. In the short grain rice cultivars, 42% had difficult; 55% had intermediate and 3% had easy panicle threshability (Figure-4.2.1a). Frequency distribution showed 53% difficult, 42% intermediate and 5% easy panicle threashability among the rice cultivars (Figure-4.2.2).

4.2.2 Panicle type

Grain compactness on the panicle is a desirable trait for rice variety (Figure-4.2.3). Out of 129 rice cultivars, 48 had compact panicle type. Long grain rice cultivarssuch as Athabinni, Bhorochalam, Binni-1, Binni-2, Cylindrical Tapi-629, Dudhkalam, Gohatibinni, Harilaxmi, Hatisail, Joalbagh, Jol, Kalabinni-1, Kanaibansi, Khorma, Molladigha, Pakhisail, Redpiebald-219, Sadajira Tapl-321, Shata and BRRI dhan39had compact panicle type but others had intermediate and open panicle type(Table-4.2.1a). Medium grain rice cultivars such as Bolonga, Dadkhani, Ganjia, Gobcha, Jhingasail-2, Gojalgoria,Kanaklata, Kataribhog-2, Lalsoru, Lohasail, Najirsail, Nunia, Paharisail, Pakibiroin,Sadamota, BR25, BRRI dhan37, BRRI dhan44 andBRRI dhan46had compact panicle type but others had intermediate and open panicle type (Table-4.2.1b). Short grain rice cultivars such as Betudhan, Chinigura, Chunikanai, Dudsail, Gurdoi, Malagrosa, Minki and BR5had compact panicle type but others had intermediate and open panicle type (Table-4.2.1c). In the long grain rice cultivars, 56% had compact; 42% had intermediate and 3% had open panicle type. In themedium grain rice cultivars, 29% had compact; 56% had intermediate and 15% had open panicle type. In theshort grain rice cultivars, 29% had compact; 55% had intermediate and 16% had open panicle type (Figure-4.2.1a). Frequency distribution showed 37% compact, 51% intermediate and 12% open panicle type among the rice cultivars (Figure-4.2.2).

4.2.3 Awn status

Awnpresents on the tip of the paddy(Figure-4.2.4). It is not a desirable character for farmers. Presence of awncreates problem to different post-harvest operations. Out of 129 rice cultivars, only 16 local rice cultivars and 1 HYVs had awn on the tip of the paddy. But rest of the local rice cultivars and HYVs oflong, medium and short grain were awnless (Table-4.2.1a, Table-4.2.1b and Table-4.2.1c). Long grain rice cultivars such as Jol, Kanaibansi, Kharmao, Redpiebald-219 and TK deep straw Tapl-773 had awn(Table-4.2.1a). Medium grain rice cultivars such asChamara, Kataribhog-232, Magoibalam,Kataribhog-1, Nunia, Rajamora, Rangabinni and BRRI dhan38had awn (Table-4.2.1b). Short grain rice cultivars such as Jabsira, Lalsaru, Rahikhama and Topaboro had awn (Table-4.2.1c). In the long grain rice cultivars, 86% had awnless but 14% had awn. In the medium grain rice cultivars, 87% had awnless but 13% had awn. In the short grain ricecultivars, 87% had awnless but 13% had awn (Figure-4.2.1a). Frequency distribution showed 87% awnless and 13% awn on the tip of the paddy among the rice cultivars (Figure-4.2.2).

4.2.4 Hull color

Hull is tough and siliceous cover enveloping the rice kernel. Rough rice had different hull colors (Figure-4.2.5). Out of 129 rice cultivars, 54 had golden hull color of whole paddy; 7had golden with different mixed hull color of whole paddy; 29 had straw hull color of whole paddy; 18 had black hull color of whole paddy; 2 had black with different mixed hull color of whole paddy as well as 19 had purple hull color of whole paddy. But most of the HYVs had golden hull color of whole paddyexcept BRRI dhan33 and BRRI dhan34, which had straw hull color (Table-4.2.1a, Table-4.2.1b and Table-4.2.1c). Long grain local rice cultivarssuch as Dudhkalam, Dudsar Tapal-146, Harilaxmi, Joalbagh, Lathamona, Neda, Patnai-231and Sadajira Tapl-321 had only golden hull color not mixed with other color(Table-4.2.1a). Medium grain local rice cultivars such as Bariksail, Bolonga, Dadkhani, Ganjia, Hijli, Kataribhog-232, Kanaklata,Kataribhog-1, Kataribhog-2, Kumragoir,Maloti, Najirsail, Nizersail, Paharisail and Tilokkajal had only golden hull color not mixed with other color (Table-4.2.1b). Short grain local rice cultivars such as Binniphul, Chinisagor, Chinigura, Dudsail, Gurdoi, Jirakatari-1, Jirakatari-2, Khasha, Malagrosa, Nurior, Pajam, Sorukamina and Uknimadhu had only golden hull color not mixed with other color (Table-4.2.1c). In the long grain rice cultivars, 39% had golden; 36% had straw; 14% had black and 11% had purple hull color. In the medium grain rice cultivars, 47% had golden; 19% had straw; 15% had black and 19% had purple hull color. In the short grain rice cultivars, 58% had golden; 13% had straw; 19% had black and 10% had purple hull color (Figure-4.2.1a). Frequency distribution showed 47% golden, 22% straw, 16% black and 15% purple hull color among the rice cultivars (Figure-4.2.2).

4.2.5 Pericarp color

A thin fibrous layer beneath the hull is called pericarp.It is normally considered as the outermost layer of the rice bran.Various pigments accumulate in the pericarp and are responsible for different pericarpcolor (Figure-4.2.6). Out of 129 rice cultivars, 46 cultivars had red pericarp but rest of the cultivars had brown pericarp. Red pericarp was shown only in local rice cultivars but not in HYVs. Long grain rice cultivars such as Athabinni, Bhorochalam, Binni-1, Binni-2, Depa, Hatisail, Jingasail-1, Joalbagh, Jol, Kalabinni-1, Kalimanik, Karailadhan, Kharmao, Khorma, Molladigha, Pakhisail, Shithabhog and

T.R.Aman had red pericarp(Table-4.2.1a). Medium grain rice cultivars such as Bariksail, Boylam, Changai, Dholagachha, Ganjia, Gobcha, Hashfol, Jhingasail-2, Jhoshua, Joyna, Kajalsail, Kalabinni-2, Kalisayta, Ledabinni, Magoibalam, Motichak, Nunia, Pakibiroin, Poushmoricha, Putidepa, Rajamora, Rangabinni and Tilkapur had red pericarp(Table-4.2.1b). Short grain rice cultivars such as Betudhan, Binniphul, Michisail, Rahikhama and Topaboro had red pericarp (Table-4.2.1c). In the long grain rice cultivars, 44% had red and 56% had brown pericarp color. In the medium grain rice cultivars, 37% had red and 63% had brown pericarp color. In the short grain rice cultivars, 16% had red and 84% had brown pericarp color (Figure-4.2.1b). Frequency distribution showed 36% red and 64% brown pericarp color among the rice cultivars (Figure-4.2.2).

4.2.6 Size and shape

Grain size and shape has been widely accepted as a complex trait. Size and shape of rough rice(Figure-4.2.8) is an important quality character for milling process.Long slender (LS) grain is known as premium quality rice, which has higher market price in the world market. Out of 129 milled rice cultivars, 16 had long slender (LS); 20 had long bold (LB); 3 had medium slender (MS); 53 had medium bold (MB); 6 had medium round (MR); 19 had short bold (SB) as well as 12 had short round (SR) type size and shape (Table-4.2.1a, Table-4.2.1b and Table-4.2.1c). Long grain rice cultivars such as Bhorochalam, Gohatibinni, Kalabinni-1, Kanaibansi, Karailadhan, Kharmao, Khorma, Lathamona, Neda, Pakhisail, Patnai-231, Redpiebald-219, Shata, T.R.Aman, TK deep straw Tapl-773 and BRRI dhan39 had long slender (LS) type size and shape(Table-4.2.1a). Medium grain rice cultivars such as Kataribhog-232, Lalsoru and BRRI dhan38 had medium slender (MS) type size and shape (Table-4.2.1b).Short grain rice cultivars such as Chinisagor, Chinigura, Jabsira, Kalasaru, Jirakatari-1, Jirakatari-2, Kalijira, Khasha, Lalsaru, Laxmikajol, Malagrosa, Michisail, Nurior, Pajam, Rahikhama, Sorukamina, Surjyamukhisangla, Uknimadhu and BRRI dhan34had short bold (SB) type size and shape (Table-4.2.1c). In the long grain rice cultivars, 44% had slender group and 56% had bold group. In the medium grain rice cultivars, 5% had slender group; 10% had round group and 85% had bold group. In the short grain rice cultivars, 39% had round group and 61% had bold group but slender group had not been found here (Figure-4.2.1b). Frequency distribution showed 15% slender group, 14% round group and 71% bold group of shape among the rice cultivars (Figure-4.2.2).

4.2.7 Chalkiness

Chalkiness of rice is the white portion in the endosperm (Figure-4.2.7). It occurs due to loose packing of starch granules and protein bodies (Del Rosario *et al.,* 1968).Translucent grains (no chalkiness in the endosperm) have a higher market value and are generally preferred by consumers. Out of 129 rice cultivars, 85 had translucent grain; 26 had white belly grain; 8 had white center grain and 10 had opaque grain.In local rice cultivars, 71 had translucent grain; 21 had white belly grain; 7 had white center grain and 10 had opaque grainbut in HYVs, 14 had translucent grain; 5 had white belly grain and 1 had white center grain (Table-4.2.1a, Table-4.2.1b and Table-4.2.1c). Long grain rice cultivars such as Bhorochalam, Depa, Dudsar Tapal-146, Harilaxmi, Jingasail-1, Joalbagh, Karailadhan, Lathamona, Neda, Pakhisail, Patnai-231, Redpiebald-219, Shithabhog,Sadajira Tapl-321, Shata, T.R.Aman, TK deep straw Tapl-773, BR23, BRRI dhan30, BRRI dhan39 and BRRI dhan41 had translucent grain but Kanaibansi, Binni-1, Binni-2, Khorma, Cylindrical Tapi-629, Kalabinni-1, Athabinni and Gohatibinni had opaque grain (Table-4.2.1a). Medium grain rice cultivars such as Bariksail, Bolonga, Chamara, Changai, Dadkhani, Ganjia, Gobcha, Hashfol, Hijli, Jhoshua, Kalabinni-2, Magoibalam,Kataribhog-232, Kataribhog-1, Nunia, Malsira, Kataribhog-2, Gojalgoria, Kanaklata, Lalbinni, Lalmota, Lalsoru, Lohasail, Najirsail, Nizersail, Rajamora, Shamrosh, Somondori, Tilkapur, BR4, BR10, BR11, BR25, BRRI dhan32, BRRI dhan37, BRRI dhan38 and BRRI dhan49 had translucent grain but Ledabinni and Rangabinni had opaque grain (Table-4.2.1b). Short grain rice cultivars such as Baoijhaki, Betudhan, Binniphul, Chinisagor, Chinigura, Chunikanai, Dudsail, Gurdoi, Jabsira, Jirakatari-1, Jirakatari-2, Kalasaru, Kalijira, Khasha, Lalsaru, Laxmikajol, Malagrosa, Michisail, Nurior, Pajam, Rahikhama, Sorukamina, Surjyamukhisangla, Tulsimala, Uknimadhu, BR5 and BRRI dhan34 had translucent grain (Table-4.2.1c). In the long grain rice cultivars, 58.4% had translucent;11.1% had white belly; 8.3% had white center and 22.2% had opaque grain. In the medium grain rice cultivars, 60% had translucent; 32% had white belly; 5% had white center and 3% had opaque grain. In the short grain rice cultivars, 87% had translucent; 7% had white belly and 6% had white center grain (Figure-4.2.1b). Frequency distribution showed 66% translucent, 20% white belly, 6% white center and 8% opaque grain among the rice cultivars (Figure-4.2.2).

4.2.8 Appearance

The three-dimensional shape of rice grain(measured as grain length, width and thickness) is one of the most important components of grain appearance.Rice is consumed as whole intake milled rice grain. So, the general appearance of milled rice is important in judging the quality of rice.Out of 129 rice cultivars,TK deep straw Tapl-773 had excellent appearance. Local rice cultivars such as Karailadhan, Pakhisail, Shata, Patnai-231, Redpiebald-219, Kanaklata, Kataribhog-232, Kataribhog-1, Kataribhog-2, Lalbinni, Najirsail, Nizersail, Chinisagor, Chunikanai, Jabsira, Khasha and Malagrosa as well as HYVs such as BRRI dhan30, BRRI dhan37, BRRI dhan38andBRRI dhan39 had very good appearance (Table-4.2.1a, Table-4.2.1b and Table-4.2.1c). In the long grain rice cultivars, 3% had excellent, 19% had very good and 78% had good appearance. In the medium grain rice cultivars, 15% had very good and 85% had good appearance. In the short grain rice cultivars, 16% had very good and 84% had good appearance (Figure-4.2.1b). Frequency distribution showed1% excellent, 16% very good and 83% good appearance among the rice cultivars (Figure-4.2.2).

4.2.9 Length, breadth and L/B ratio of paddy, brown rice and milled rice

Paddy length is one of the most important quality characters for milling process. Long paddy length requires special attention, because it is very prone to higher breakage in milling. Long milled rice length (>6 mm), lower breadth (<2 mm) and higher L/B ratio (>3.2) indicate superior rice grain with premium quality. There were 36 long,62 medium and 31 short grain among the total rice cultivars. Prominent cultivars such as Khorma, Boradudhkalam, Patnai-231, Shata, Dudhkalam, Kalabinni-1, Neda, Pakhisail and Karailadhan had the highest range of milled rice length of (7.0-7.4) mm and paddy length of (10.4-12.1) mm.Among these, Khorma, Neda, Pakhisail and Karailadhan had the lower range of milled rice breadth of (1.8-1.9) mm and the highest range of L/B ratio of (3.9-4.2) (Table-4.2.2a, Table-4.2.2b and Table-4.2.2c).

In the case of long grain paddy, Karailadhan had the highest paddy length (12.1 mm) but Harilaxmi had the lowest paddy length (8.8 mm). Cultivars of Karailadhan, Pakhisail and Neda had more than 11 mm paddy length. In the case of long grain brown rice, Neda had the highest brown rice length (8.3 mm) butboth Joalbagh and Harilaxmi had the lowest brown rice length (6.4 mm). In the case of long grain milled rice, both Karailadhan and Pakhisail had the highest milled rice length (7.4 mm) but BRRI dhan30 had the lowest milled rice length (6 mm). Both Dudhkalam and Boradudhkalam had the highest milled rice breadth (2.7 mm) butboth Karailadhan and Neda had the lowest milled rice breadth (1.8

mm). Karailadhan and Neda both had the highest milled rice L/B ratio (4.2) but Molladigha had the lowest milled rice L/B ratio (2.4) (Table-4.2.2a). In the long grain rice cultivars, length, breath andL/B ratio of local paddy as well aslocal milled rice had higher than the HYVs (Figure-4.2.9).

In the case of medium grain paddy, Jhoshua, Dadkhani and BRRI dhan44 had the highest paddy length (9.1 mm) but Poushmoricha had the lowest paddy length (7.2 mm). In the case of medium grain brown rice, both Jhoshua and BRRI dhan38 had the highest brown rice length (6.5 mm) but Poushmoricha had the lowest brown rice length (5.1 mm). In the case of medium grain milled rice, Jhoshua, Motichak and BRRI dhan38 had the highest milled rice length (6.0 mm) but Kumragoir, Dholagachha, Poushmoricha and Gobcha had the lowest milled rice length (5 mm). Nakchi and Sadamota both had the highest milled rice breadth (2.9 mm) but Lalsoru had the lowest milled rice breadth (1.6 mm). Lalsoru had the highest milled rice L/B ratio (3.3) but Kumragoir had the lowest milled rice L/B ratio (1.8) (Table-4.2.2b). In the medium grain rice cultivars, breadth of local paddy andlocal brown rice as well as breadth and lengthof local milled rice had higher than the HYVs (Figure-4.2.9).

In the case of short grain paddy, Pajam had the highest paddy length (7.8 mm) but Sorukamina had the lowest paddy length (5.8 mm). In the case of short grain brown rice, Pajam had the highest brown rice length (5.6 mm) but Khasha and Tulsimala both had the lowest brown rice length (4 mm). In the case of short grain milled rice, Betudhan had the highest milled rice length (5.0 mm) but Khasha, Tulsimala, Sorukamina and Surjyamukhisangla had the lowest milled rice length (3.7 mm). Nariabochi and Minki both had the highest milled rice breadth (2.9 mm) but Lalsaru and Jirakatari-2 both had the lowest milled rice breadth (1.7 mm). Kalasaru had the highest milled rice L/B ratio (2.7) but Tulsimala had the lowest milled rice L/B ratio (1.4) (Table-4.2.2c). In the short grain rice cultivars, length as well asbreadth of local paddy, local brown rice andlocal milled rice had higher than the HYVs (Figure-4.2.9).

4.2.10 Correlation of length, breadth and L/B ratio

Pearson correlation coefficients for relationships had among length, breadth and L/B ratio of paddy, brown rice and milled rice. Paddy L/B ratio was highly significant and positively correlated with brown rice L/B ratio (r=1.000, p<0.01)and milled rice (L/B) ratio (r=1.000, p<0.01). Milled rice length was significant and positively correlated with brown rice length (r=1.000, p<0.05) and paddy length (r=0.998, p<0.05). Even more, all parameters were positively correlated with each other except the above relation (Table-4.2.3).

4.2.11 Cluster analysis of length, breadth and L/B ratio

Length, breadth and L/B ratio ofpaddy, brown rice and milled rice of all rice cultivars based clustering provided 3 clusters: one cluster at level below 5 and two clusters at level 10. Paddy breath, paddy L/B ratio, brown rice breadth, brown rice L/B ratio, milled rice breadth and milled rice L/B ratiohad close relationship with each other in cluster-1 at level below-5. Similarly, brown rice length and milled rice length had close relationship with each other in cluster-2at level 10. But paddy length had week relationship with brown rice length and milled rice length in cluster-3 at level 10(Figure-4.2.10).

Table-4.2.1a: Qualitative traits of morphological and physical properties for 36 long grain rice cultivars

Sl. No.	Cultivars	Panicle threshability	Panicle type	Awn status	Hull color	Pericarp color	Size & Shape	Chalkiness	Appearance
1	Athabinni	Intermediate	Compact	–	Golden blackish	Red	LB	Opaque	Good
2	Bhorochalam	Difficult	Compact	–	Straw	Red	LS	Tr	Good
3	Binni-1	Intermediate	Compact	–	Purple	Red	LB	Opaque	Good
4	Binni-2	Difficult	Compact	–	Purple	Red	LB	Opaque	Good
5	Boradudhkalam	Intermediate	Intermediate	–	Straw	Brown	LB	Wb5	Good
6	Cylindrical Tapi-629	Difficult	Compact	–	Golden (Black tip)	Brown	LB	Opaque	Good
7	Depa	Difficult	Intermediate	–	Purple	Red	LB	Tr	Good
8	Dudhkalam	Difficult	Compact	–	Golden	Brown	LB	Wb5	Good
9	Dudsar Tapal-146	Difficult	Intermediate	–	Golden	Brown	LB	Tr	Good
10	Gohatibinni	Intermediate	Compact	–	Black with Straw	Brown	LS	Opaque	Good
11	Harilaxmi	Difficult	Compact	–	Golden	Brown	LB	Tr	Good
12	Hatisail	Difficult	Compact	–	Black	Red	LB	Wc1	Good
13	Jingasail-1	Difficult	Intermediate	–	Purple	Red	LB	Tr	Good
14	Joalbagh	Difficult	Compact	–	Golden	Red	LB	Tr	Good
15	Jol	Intermediate	Compact	+	Straw	Red	LB	Wb1	Good
16	Kalabinni-1	Intermediate	Compact	–	Black	Red	LS	Opaque	Good
17	Kalimanik	Intermediate	Open	–	Black	Red	LB	Wc5	Good
18	Kanaibansi	Difficult	Compact	+	Straw	Brown	LS	Opaque	Good
19	Karaildhan	Intermediate	Intermediate	–	Straw	Red	LS	Tr	V.good
20	Kharmao	Difficult	Intermediate	+	Straw	Red	LS	Wc9	Good
21	Khorma	Intermediate	Compact	–	Straw	Red	LS	Opaque	Good
22	Lathamona	Intermediate	Intermediate	–	Golden	Brown	LS	Tr	Good
23	Molladigha	Difficult	Compact	–	Straw	Red	LB	Wb5	Good
24	Neda	Intermediate	Intermediate	–	Golden	Brown	LS	Tr	Good
25	Pakhisail	Difficult	Compact	–	Straw	Red	LS	Tr	V.good
26	Patnai-231	Difficult	Intermediate	–	Golden	Brown	LS	Tr	V.good
27	Redpiebald-219	Difficult	Compact	+	Straw	Brown	LS	Tr	V.good
28	Sadajira Tapl-321	Difficult	Compact	–	Golden	Brown	LB	Tr	Good
29	Shata	Intermediate	Compact	–	Straw	Brown	LS	Tr	V.good
30	Shithabhog	Intermediate	Intermediate	–	Black	Red	LB	Tr	Good
31	T.R.Aman	Intermediate	Intermediate	–	Straw	Red	LS	Tr	Good
32	TK deep straw Tapl-773	Intermediate	Intermediate	+	Straw	Brown	LS	Tr	Excellent
33	BR23	Difficult	Intermediate	–	Golden	Brown	LB	Tr	Good
34	BRRI dhan30	Difficult	Intermediate	–	Golden	Brown	LB	Tr	V.good
35	BRRI dhan39	Intermediate	Compact	–	Golden	Brown	LS	Tr	V.good
36	BRRI dhan41	Intermediate	Intermediate	–	Golden	Brown	LB	Tr	Good

Table-4.2.1b: Qualitative traits of morphological and physical properties for 62 medium grain rice cultivars

Sl.No.	Cultivars	Panicle threshability	Panicle type	Awn status	Hull color	Pericarp color	Size&Shape	Chalkiness	Appearance
1	Bariksail	Difficult	Intermediate	–	Golden	Red	MB	Tr	Good
2	Bolonga	Intermediate	Compact	–	Golden	Brown	MB	Tr	Good
3	Boylam	Intermediate	Intermediate	–	Straw	Red	MB	Wb5	Good
4	Chamara	Easy	Intermediate	+	Straw	Brown	MB	Tr	Good
5	Changai	Difficult	Intermediate	–	Black	Red	MB	Tr	Good
6	Dadkhani	Intermediate	Compact	–	Golden	Brown	MB	Tr	Good
7	Dholagachha	Easy	Intermediate	–	Straw	Red	MR	Wb1	Good
8	Ganjia	Intermediate	Compact	–	Golden	Red	MB	Tr	Good
9	Gobcha	Intermediate	Compact	–	Straw	Red	MR	Tr	Good
10	Gojalgoria	Intermediate	Compact	–	Blackish purple	Brown	MB	Tr	Good
11	Hashfol	Difficult	Intermediate	–	Straw	Red	MB	Tr	Good
12	Hathazi	Difficult	Open	–	Purple	Brown	MB	Wb5	Good
13	Hijli	Intermediate	Intermediate	–	Golden	Brown	MB	Tr	Good
14	Jhingasail-2	Difficult	Compact	–	Purple	Red	MB	Wb1	Good
15	Jhoshua	Difficult	Open	–	Purple	Red	MB	Tr	Good
16	Joyna	Intermediate	Intermediate	–	Purple	Red	MB	Wb5	Good
17	Kajalsail	Difficult	Intermediate	–	Black	Red	MB	Wb5	Good
18	Kalabinni-2	Intermediate	Intermediate	–	Black(light)	Red	MB	Tr	Good
19	Kalisayta	Intermediate	Intermediate	–	Black	Red	MB	Wb5	Good
20	Kanaklata	Difficult	Compact	–	Golden	Brown	MB	Tr	V.good
21	Kataribhog-232	Intermediate	Intermediate	+	Golden	Brown	MS	Tr	V.good
22	Kataribhog-1	Intermediate	Open	+	Golden	Brown	MB	Tr	V.good
23	Kataribhog-2	Intermediate	Compact	–	Golden	Brown	MB	Tr	V.good
24	Kumragoir	Easy	Intermediate	–	Golden	Brown	MR	Wb1	Good
25	Lalbinni	Intermediate	Intermediate	–	Purple	Brown	MB	Tr	V.good
26	Lalmota	Intermediate	Intermediate	–	Purple	Brown	MB	Tr	Good
27	Lalsoru	Difficult	Compact	–	Purple	Brown	MS	Tr	Good
28	Ledabinni	Intermediate	Intermediate	–	Black	Red	MB	Opaque	Good
29	Lohasail	Difficult	Compact	–	Golden with light purple	Brown	MB	Tr	Good
30	Magoibalam	Difficult	Open	+	Purple	Red	MB	Tr	Good
31	Maloti	Difficult	Intermediate	–	Golden	Brown	MB	Wc1	Good
32	Malsira	Difficult	Intermediate	–	Purple	Brown	MB	Tr	Good

Sl.No.	Cultivars	Panicle threshability	Panicle type	Awn status	Hull color	Pericarp color	Size&Shape	Chalkiness	Appearance
33	Motichak	Intermediate	Intermediate	–	Black	Red	MB	Wb5	Good
34	Najirsail	Intermediate	Compact	–	Golden	Brown	MB	Tr	V.good
35	Nakchi	Difficult	Open	–	Straw	Brown	MR	Wb5	Good
36	Nizersail	Difficult	Open	–	Golden	Brown	MB	Tr	V.good
37	Nunia	Difficult	Compact	+	Straw	Red	MB	Tr	Good
38	Paharisail	Intermediate	Compact	–	Golden	Brown	MB	Wc1	Good
39	Pakibiroin	Difficult	Compact	–	Straw	Red	MR	Wb1	Good
40	Poushmoricha	Difficult	Intermediate	–	Black	Red	MB	Wb5	Good
41	Putidepa	Difficult	Open	–	Straw	Red	MB	Wb5	Good
42	Rajamora	Difficult	Intermediate	+	Straw	Red	MB	Tr	Good
43	Rangabinni	Difficult	Intermediate	+	Purple	Red	MB	Opaque	Good
44	Sadamota	Easy	Compact	–	Straw	Brown	MR	Wb5	Good
45	Shamrosh	Difficult	Open	–	Purple	Brown	MB	Tr	Good
46	Somondori	Difficult	Intermediate	–	Purple	Brown	MB	Tr	Good
47	Tilkapur	Easy	Intermediate	–	Black	Red	MB	Tr	Good
48	Tilokkajal	Difficult	Open	–	Golden	Brown	MB	Wb1	Good
49	BR4	Difficult	Intermediate	–	Golden	Brown	MB	Tr	Good
50	BR10	Difficult	Intermediate	–	Golden	Brown	MB	Tr	Good
51	BR11	Difficult	Intermediate	–	Golden	Brown	MB	Tr	Good
52	BR22	Difficult	Intermediate	–	Golden	Brown	MB	Wc5	Good
53	BR25	Difficult	Compact	–	Golden	Brown	MB	Tr	Good
54	BRRI dhan31	Difficult	Intermediate	–	Golden	Brown	MB	Wb1	Good
55	BRRI dhan32	Difficult	Intermediate	–	Golden	Brown	MB	Tr	Good
56	BRRI dhan33	Difficult	Intermediate	–	Straw	Brown	MB	Wb5	Good
57	BRRI dhan37	Difficult	Compact	–	Golden	Brown	MB	Tr	V.good
58	BRRI dhan38	Difficult	Intermediate	+	Golden	Brown	MS	Tr	V.good
59	BRRI dhan40	Difficult	Intermediate	–	Golden	Brown	MB	Wb1	Good
60	BRRI dhan44	Intermediate	Compact	–	Golden	Brown	MB	Wb1	Good
61	BRRI dhan46	Intermediate	Compact	–	Golden	Brown	MB	Wb1	Good
62	BRRI dhan49	Intermediate	Intermediate	–	Golden	Brown	MB	Tr	Good

Table-4.2.1c: Qualitative traits of morphological and physical properties for 31 short grain rice cultivars

Sl. No.	Cultivars	Panicle threshability	Panicle type	Awn status	Hull color	Pericarp color	Size & Shape	Chalkiness	Appearance
1	Baoijhaki	Intermediate	Open	−	Purple	Brown	SR	Tr	Good
2	Betudhan	Difficult	Compact	−	Straw	Red	SR	Tr	Good
3	Binniphul	Intermediate	Intermediate	−	Golden	Red	SR	Tr	Good
4	Chinisagor	Intermediate	Intermediate	−	Golden	Brown	SB	Tr	V.good
5	Chinigura	Intermediate	Compact	−	Golden	Brown	SB	Tr	Good
6	Chunikanai	Intermediate	Compact	−	Purple	Brown	SR	Tr	V.good
7	Dudsail	Difficult	Compact	−	Golden	Brown	SR	Tr	Good
8	Gurdoi	Difficult	Compact	−	Golden	Brown	SR	Tr	Good
9	Jabsira	Easy	Intermediate	+	Golden with black	Brown	SB	Tr	V.good
10	Jirakatari-1	Intermediate	Open	−	Golden	Brown	SB	Tr	Good
11	Jirakatari-2	Intermediate	Intermediate	−	Golden	Brown	SB	Tr	Good
12	Kalasaru	Intermediate	Compact	−	Black	Brown	SB	Tr	Good
13	Kalijira	Difficult	Intermediate	−	Black	Brown	SB	Tr	Good
14	Khasha	Difficult	Intermediate	−	Golden	Brown	SB	Tr	V.good
15	Lalsaru	Difficult	Intermediate	+	Golden blakish	Brown	SB	Tr	Good
16	Laxmikajol	Intermediate	Intermediate	−	Black	Brown	SB	Tr	Good
17	Malagrosa	Difficult	Compact	−	Golden	Brown	SB	Tr	V.good
18	Michisail	Intermediate	Intermediate	−	Black	Red	SB	Tr	Good
19	Minki	Difficult	Compact	−	Golden(Black tip)	Brown	SR	Wb1	Good
20	Murchmut	Intermediate	Open	−	Black	Brown	SR	Wc1	Good
21	Nariabochi	Intermediate	Open	−	Purple	Brown	SR	Wb5	Good
22	Nurior	Difficult	Open	−	Golden	Brown	SB	Tr	Good
23	Pajam	Intermediate	Intermediate	−	Golden	Brown	SB	Tr	Good
24	Rahikhama	Difficult	Intermediate	+	Straw	Red	SB	Tr	Good
25	Sorukamina	Intermediate	Intermediate	−	Golden	Brown	SB	Tr	Good
26	Surjyamukhisangla	Intermediate	Intermediate	−	Black	Brown	SB	Tr	Good
27	Topaboro	Difficult	Intermediate	+	Straw	Red	SR	Wc5	Good
28	Tulsimala	Intermediate	Intermediate	−	Golden(Black tip)	Brown	SR	Tr	Good
29	Uknimadhu	Intermediate	Intermediate	−	Golden	Brown	SB	Tr	Good
30	BR5	Difficult	Compact	−	Golden	Brown	SR	Tr	Good
31	BRRI dhan34	Difficult	Intermediate	−	Straw	Brown	SB	Tr	Good

Table-4.2.2a:Variation of length, breadth and L/B ratio associated with paddy, brown rice and milled rice for 36 long grain rice cultivars

Sl. No.	Cultivars	Paddy (L) mm	Paddy (B) mm	Paddy (L/B)	Brown rice (L) mm	Brown rice (B) mm	Brown rice (L/B)	Milled rice (L) mm	Milled rice (B) mm	Milled rice (L/B)
1	Athabinni	10.1±0.31	2.9±0.08	3.7±0.21	7.0±0.19	2.2±0.04	3.1±0.15	6.4±0.21	2.1±0.03	3.0±0.06
2	Bhorochalam	9.8±0.29	2.7±0.08	3.5±0.10	7.0±0.20	2.3±0.07	3.2±0.10	6.7±0.24	2.2±0.06	3.1±0.15
3	Binni-1	9.7±0.26	2.9±0.08	3.4±0.10	6.8±0.13	2.3±0.06	3.1±0.12	6.3±0.24	2.1±0.06	3.0±0.00
4	Binni-2	9.4±0.18	2.6±0.08	3.6±0.06	6.7±0.18	2.2±0.07	3.0±0.26	6.5±0.24	2.1±0.06	3.0±0.32
5	Boradudhkalam	10.7±0.39	3.2±0.14	3.5±0.26	7.9±0.33	2.7±0.11	3.1±0.10	7.1±0.18	2.7±0.08	2.7±0.10
6	Cylindrical Tapi-629	10.7±0.34	3.2±0.09	3.3±0.17	7.5±0.21	2.5±0.06	3.1±0.12	6.9±0.29	2.4±0.07	2.9±0.12
7	Depa	10.3±0.31	3.0±0.06	3.4±0.06	7.5±0.19	2.5±0.07	3.1±0.10	6.9±0.23	2.4±0.06	2.8±0.10
8	Dudhkalam	10.4±0.27	3.3±0.09	3.1±0.06	7.7±0.15	2.8±0.10	2.8±0.12	7.3±0.18	2.7±0.10	2.7±0.15
9	Dudsar Tapal-146	9.8±0.24	2.8±0.10	3.6±0.21	6.9±0.16	2.4±0.08	2.8±0.06	6.3±0.21	2.3±0.06	2.8±0.06
10	Gohatibinni	10.1±0.24	2.8±0.09	3.4±0.12	7.0±0.16	2.2±0.06	3.2±0.20	6.4±0.27	2.1±0.07	3.1±0.15
11	Harilaxmi	8.8±0.27	2.7±0.10	3.2±0.06	6.4±0.19	2.4±0.06	2.7±0.00	6.2±0.23	2.3±0.06	2.7±0.12
12	Hatisail	10.0±0.19	3.0±0.06	3.4±0.12	7.2±0.12	2.6±0.07	2.8±0.10	6.7±0.22	2.4±0.11	2.8±0.12
13	Jingasail-1	8.9±0.27	2.6±0.08	3.3±0.15	6.5±0.18	2.3±0.09	2.8±0.06	6.2±0.19	2.2±0.08	2.8±0.10
14	Joalbagh	9.0±0.47	2.9±0.11	2.9±0.15	6.4±0.24	2.5±0.12	2.7±0.17	6.2±0.16	2.3±0.07	2.7±0.15
15	Jol	9.6±0.23	2.9±0.15	3.3±0.15	6.8±0.13	2.4±0.10	2.8±0.06	6.6±0.27	2.4±0.05	2.8±0.10
16	Kalabinni-1	10.9±0.29	2.9±0.10	3.6±0.26	7.5±0.19	2.4±0.06	3.2±0.10	7.2±0.17	2.3±0.07	3.1±0.12
17	Kalimanik	9.9±0.29	3.0±0.12	3.4±0.15	7.1±0.31	2.5±0.11	2.8±0.10	6.9±0.27	2.4±0.06	2.8±0.06
18	Kanaibansi	10.5±0.36	2.4±0.05	4.4±0.21	7.2±0.24	2.0±0.05	3.5±0.26	6.8±0.24	2.0±0.05	3.5±0.21
19	Karailadhan	12.1±0.31	2.3±0.08	5.2±0.15	7.9±0.19	1.8±0.08	4.3±0.26	7.4±0.17	1.8±0.09	4.2±0.31
20	Kharmao	10.5±0.27	2.5±0.10	4.2±0.20	7.4±0.18	2.1±0.08	3.5±0.23	6.8±0.29	2.2±0.20	3.2±0.35
21	Khorma	10.9±2.18	2.4±0.06	4.7±0.06	7.6±0.20	1.9±0.08	4.0±0.06	7.0±0.35	1.9±0.04	3.9±0.30
22	Lathamona	10.1±0.33	2.5±0.11	4.1±0.10	6.9±0.22	2.1±0.07	3.3±0.10	6.5±0.22	2.0±0.06	3.2±0.12
23	Molladigha	9.9±0.30	3.4±0.11	2.9±0.06	7.0±0.19	2.8±0.07	2.6±0.06	6.4±0.24	2.6±0.10	2.4±0.12
24	Neda	11.2±0.30	2.3±0.06	4.8±0.15	8.3±0.30	1.9±0.07	4.2±0.12	7.3±0.29	1.8±0.10	4.2±0.55
25	Pakhisail	11.3±0.52	2.6±0.17	4.1±0.21	8.0±0.24	2.2±0.15	3.9±0.70	7.4±0.19	1.9±0.17	3.9±0.46
26	Patnai-231	10.5±0.26	2.8±0.09	3.8±0.10	7.5±0.17	2.4±0.06	3.2±0.10	7.3±0.22	2.2±0.08	3.2±0.15
27	Redpiebald-219	10.0±0.26	2.5±0.07	4.0±0.12	6.9±0.15	2.1±0.06	3.3±0.10	6.6±0.23	2.1±0.08	3.2±0.15
28	Sadajira Tapl-321	9.6±0.25	2.7±0.07	3.7±0.15	6.9±0.24	2.3±0.04	3.1±0.26	6.5±0.20	2.2±0.08	3.0±0.15
29	Shata	10.6±0.36	2.7±0.11	4.0±0.20	7.8±0.24	2.2±0.06	3.7±0.06	7.2±0.28	2.2±0.08	3.5±0.10
30	Shithabhog	10.0±0.36	2.9±0.10	3.4±0.36	7.0±0.15	2.5±0.07	2.9±0.06	6.8±0.18	2.4±0.08	2.8±0.21
31	T.R.Aman	10.5±0.29	2.7±0.13	4.2±0.31	7.3±0.16	2.2±0.08	3.2±0.06	6.8±0.29	2.1±0.05	3.2±0.25
32	TK deep straw Tapl-773	10.1±0.40	2.5±0.10	3.9±0.10	7.3±0.41	2.2±0.09	3.4±0.15	6.7±0.29	2.1±0.06	3.3±0.12
33	BR23	9.5±0.30	2.8±0.07	3.5±0.15	7.0±0.21	2.4±0.08	3.0±0.21	6.7±0.29	2.3±0.06	3.0±0.21
34	BRRI dhan30	9.3±0.36	2.6±0.05	3.4±0.10	6.7±0.26	2.2±0.06	3.1±0.06	6.0±0.19	2.1±0.10	2.7±0.21
35	BRRI dhan39	9.8±0.24	2.6±0.09	3.9±0.17	7.1±0.15	2.2±0.06	3.4±0.12	6.6±0.20	2.1±0.06	3.2±0.10
36	BRRI dhan41	9.5±0.30	2.8±0.09	3.2±0.15	6.9±0.18	2.4±0.06	3.0±0.15	6.5±0.19	2.3±0.08	2.8±0.10
Range		**8.8-12.1**	**2.3-3.4**	**2.9-5.2**	**6.4-8.3**	**1.8-2.8**	**2.6-4.3**	**6.0-7.4**	**1.8-2.7**	**2.4-4.2**
Mean±SD		**10.1±0.69**	**2.8±0.27**	**3.7±0.52**	**7.2±0.46**	**2.3±0.23**	**3.2±0.41**	**6.7±0.38**	**2.2±0.22**	**3.1±0.42**
CV%		**7**	**10**	**14**	**6**	**10**	**13**	**6**	**10**	**14**
SE (Standard error)		**0.1896**	**0.578-01**	**0.9609**	**0.1298**	**0.4676-01**	**0.1025**	**0.1329**	**0.507-01**	**0.1179**
LSD (0.05)		**0.5349**	**0.1630**	**0.2710**	**0.3661**	**0.1318**	**0.289**	**0.3748**	**0.1431**	**0.3326**

Table-4.2.2b:Variation of length, breadth and L/B ratio associated with paddy, brown rice and milled rice for 62 medium grain rice cultivars

Sl. No.	Cultivars	Paddy (L) mm	Paddy (B) mm	Paddy (L/B)	Brown rice (L) mm	Brown rice (B) mm	Brown rice (L/B)	Milled rice (L) mm	Milled rice (B) mm	Milled rice (L/B)
1	Bariksail	8.0±0.14	2.6±0.15	3.0±0.06	5.8±0.13	2.2±0.12	2.5±0.06	5.5±0.19	2.2±0.15	2.4±0.10
2	Bolonga	7.8±0.24	2.7±0.08	2.9±0.15	5.5±0.16	2.3±0.06	2.4±0.06	5.2±0.26	2.3±0.07	2.2±0.20
3	Boylam	8.8±0.36	3.1±0.12	2.9±0.25	6.2±0.30	2.6±0.11	2.3±0.10	5.6±0.44	2.4±0.10	2.3±0.12
4	Chamara	8.4±0.17	2.9±0.17	2.9±0.17	6.1±0.12	2.4±0.14	2.5±0.20	5.6±0.33	2.4±0.15	2.5±0.06
5	Changai	8.6±0.28	2.9±0.11	3.0±0.15	6.2±0.20	2.5±0.09	2.4±0.15	5.7±0.15	2.4±0.11	2.4±0.06
6	Dadkhani	9.1±0.33	2.2±0.08	4.2±0.25	6.1±0.28	1.8±0.06	3.3±0.15	5.6±0.21	1.9±0.12	3.0±0.17
7	Dholagachha	7.7±0.13	3.3±0.07	2.3±0.12	5.4±0.10	2.8±0.10	1.9±0.00	5.0±0.15	2.7±0.12	1.9±0.17
8	Ganjia	7.9±0.18	2.4±0.04	3.3±0.10	5.7±0.12	2.1±0.04	2.8±0.12	5.2±0.16	2.0±0.03	2.7±0.00
9	Gobcha	7.5±0.23	3.4±0.08	2.2±0.06	5.4±0.18	2.9±0.09	2.0±0.15	5.0±0.17	2.7±0.09	1.9±0.06
10	Gojalgoria	8.3±0.20	2.8±0.09	3.2±0.21	5.9±0.12	2.4±0.05	2.6±0.06	5.4±0.17	2.2±0.09	2.4±0.06
11	Hashfol	8.3±0.19	3.1±0.06	2.8±0.10	5.7±0.13	2.6±0.07	2.1±0.06	5.3±0.17	2.5±0.14	2.1±0.12
12	Hathazi	8.1±0.22	3.4±0.06	2.4±0.06	5.7±0.11	2.9±0.07	2.0±0.06	5.5±0.17	2.7±0.12	2.0±0.12
13	Hijli	8.2±0.26	2.5±0.08	3.3±0.15	5.7±0.17	2.1±0.06	2.7±0.00	5.4±0.18	2.1±0.06	2.5±0.06
14	Jhingasail-2	8.7±0.25	3.4±0.08	2.6±0.10	6.2±0.18	2.9±0.10	2.2±0.15	5.7±0.22	2.6±0.15	2.2±0.06
15	Jhoshua	9.1±0.21	2.8±0.05	3.3±0.10	6.5±0.07	2.3±0.05	2.8±0.06	6.0±0.18	2.2±0.07	2.8±0.15
16	Joyna	8.9±0.27	3.2±0.08	2.6±0.10	6.2±0.16	2.6±0.08	2.4±0.15	5.5±0.27	2.5±0.11	2.2±0.15
17	Kajalsail	8.9±0.23	3.3±0.09	2.8±0.10	6.2±0.15	2.8±0.06	2.3±0.06	5.8±0.17	2.6±0.06	2.2±0.10
18	Kalabinni-2	8.9±0.20	2.6±0.06	3.4±0.15	6.3±0.13	2.3±0.06	2.8±0.10	5.6±0.23	2.2±0.13	2.6±0.12
19	Kalisayta	8.9±0.35	3.2±0.10	2.8±0.17	6.1±0.20	2.6±0.08	2.4±0.06	5.7±0.25	2.4±0.06	2.4±0.00
20	Kanaklata	8.0±0.20	2.4±0.06	3.4±0.10	5.7±0.17	2.0±0.03	2.8±0.06	5.2±0.17	1.9±0.07	2.6±0.12
21	Kataribhog-232	8.5±0.44	2.1±0.06	4.3±0.21	5.9±0.20	1.8±0.06	3.2±0.30	5.4±0.14	1.7±0.08	3.2±0.25
22	Kataribhog-1	8.5±0.30	2.2±0.09	3.8±0.17	5.9±0.15	1.9±0.07	3.1±0.21	5.3±0.16	1.8±0.10	3.0±0.00
23	Kataribhog-2	8.3±0.20	2.3±0.09	3.8±0.17	5.8±0.14	1.9±0.06	3.2±0.10	5.1±0.33	1.8±0.07	2.9±0.10
24	Kumragoir	7.6±0.23	3.2±0.13	2.3±0.06	5.2±0.16	2.8±0.10	1.8±0.10	5.0±0.26	2.7±0.07	1.8±0.06
25	Lalbinni	8.6±0.17	2.8±0.06	3.2±0.10	6.0±0.12	2.4±0.05	2.5±0.06	5.4±0.18	2.3±0.08	2.3±0.17
26	Lalmota	8.5±0.26	3.4±0.12	2.4±0.10	6.1±0.18	3.0±0.07	2.1±0.10	5.5±0.31	2.6±0.18	2.1±0.44
27	Lalsoru	8.6±0.26	2.1±0.06	4.1±0.10	5.9±0.17	1.8±0.05	3.3±0.10	5.2±0.18	1.6±0.09	3.3±0.29
28	Ledabinni	8.2±0.26	2.8±0.10	3.0±0.00	5.8±0.16	2.4±0.06	2.6±0.00	5.8±0.18	2.2±0.08	2.6±0.15
29	Lohasail	8.2±0.31	2.9±0.07	2.9±0.12	5.8±0.20	2.5±0.06	2.4±0.00	5.6±0.17	2.5±0.09	2.3±0.12
30	Magoibalam	7.7±0.31	2.9±0.12	2.6±0.15	5.3±0.15	2.5±0.09	2.2±0.00	5.2±0.18	2.3±0.09	2.2±0.17
31	Maloti	8.1±0.11	2.7±0.06	3.0±0.06	5.8±0.08	2.4±0.05	2.5±0.12	5.2±0.12	2.2±0.07	2.3±0.06
32	Malsira	8.3±0.22	2.7±0.08	3.1±0.10	5.8±0.15	2.3±0.07	2.5±0.26	5.3±0.19	2.2±0.09	2.4±0.15
33	Motichak	9.0±0.27	3.3±0.13	2.8±0.00	6.3±0.18	2.7±0.11	2.4±0.06	6.0±0.17	2.5±0.10	2.4±0.15

Sl. No.	Cultivars	Paddy (L) mm	Paddy (B) mm	Paddy (L/B)	Brown rice (L) mm	Brown rice (B) mm	Brown rice (L/B)	Milled rice (L) mm	Milled rice (B) mm	Milled rice (L/B)
34	Najirsail	8.2±0.31	2.6±0.09	3.2±0.12	5.9±0.15	2.2±0.06	2.6±0.00	5.4±0.19	2.0±0.08	2.6±0.20
35	Nakchi	7.8±0.21	3.5±0.09	2.2±0.10	5.6±0.11	3.0±0.06	1.9±0.06	5.5±0.20	2.9±0.08	1.9±0.17
36	Nizersail	7.8±0.18	2.5±0.06	3.2±0.15	5.5±0.11	2.1±0.06	2.6±0.10	5.2±0.14	2.0±0.10	2.6±0.06
37	Nunia	8.0±0.25	2.5±0.09	3.1±0.15	5.8±0.15	2.2±0.08	2.7±0.15	5.4±0.26	2.1±0.15	2.5±0.12
38	Paharisail	7.8±0.22	2.7±0.10	3.0±0.17	5.6±0.15	2.3±0.08	2.3±0.06	5.3±0.23	2.3±0.07	2.2±0.12
39	Pakibiroin	7.5±0.28	3.4±0.07	2.3±0.06	5.3±0.21	2.9±0.10	1.9±0.17	5.1±0.17	2.8±0.11	1.9±0.15
40	Poushmoricha	7.2±0.23	3.0±0.08	2.4±0.10	5.1±0.14	2.6±0.05	2.0±0.06	5.0±0.18	2.5±0.09	2.0±0.17
41	Putidepa	8.4±0.16	3.4±0.07	2.4±0.12	6.0±0.12	2.9±0.08	2.1±0.10	5.6±0.15	2.7±0.10	2.1±0.06
42	Rajamora	8.7±0.22	3.4±0.13	2.6±0.12	6.1±0.14	2.9±0.11	2.1±0.06	5.8±0.29	2.4±0.15	2.1±0.10
43	Rangbinni	8.6±0.21	2.8±0.10	3.2±0.12	5.9±0.18	2.3±0.06	2.6±0.17	5.3±0.20	2.1±0.11	2.6±0.00
44	Sadamota	8.3±0.26	3.5±0.08	2.3±0.15	5.8±0.16	3.0±0.06	1.9±0.00	5.4±0.20	2.9±0.09	1.9±0.10
45	Shamrosh	8.5±0.20	3.0±0.08	2.9±0.10	6.0±0.11	2.6±0.08	2.3±0.12	5.5±0.17	2.3±0.14	2.3±0.12
46	Somondori	8.4±0.20	2.6±0.08	3.1±0.12	5.9±0.15	2.3±0.06	2.6±0.06	5.4±0.22	2.3±0.09	2.4±0.10
47	Tilkapur	8.4±0.17	2.9±0.08	3.0±0.10	6.0±0.12	2.5±0.06	2.5±0.12	5.7±0.22	2.4±0.08	2.3±0.06
48	Tilokkajal	8.6±0.26	3.3±0.08	2.6±0.00	6.1±0.15	2.8±0.06	2.2±0.06	5.8±0.14	2.7±0.07	2.1±0.06
49	BR4	8.2±0.24	2.7±0.07	3.0±0.00	5.8±0.17	2.3±0.05	2.5±0.06	5.3±0.21	2.2±0.08	2.3±0.15
50	BR10	7.8±0.28	2.7±0.15	2.8±0.38	5.6±0.23	2.3±0.13	2.6±0.32	5.7±0.26	2.2±0.11	2.6±0.20
51	BR11	8.5±0.27	2.8±0.22	3.4±0.40	5.9±0.22	2.5±0.15	2.5±0.15	5.7±0.21	2.2±0.18	2.5±0.15
52	BR22	8.0±0.25	2.7±0.05	2.9±0.12	5.7±0.16	2.3±0.06	2.4±0.10	5.3±0.20	2.2±0.08	2.4±0.15
53	BR25	8.6±0.38	2.7±0.11	3.1±0.15	6.0±0.20	2.3±0.10	2.6±0.12	5.3±0.37	2.1±0.11	2.6±0.20
54	BRRI dhan31	8.4±0.20	3.2±0.14	2.6±0.12	6.2±0.17	2.8±0.08	2.2±0.06	5.5±0.16	2.6±0.08	2.1±0.06
55	BRRI dhan32	8.6±0.23	2.6±0.14	3.2±0.17	6.2±0.18	2.2±0.09	2.9±0.06	5.6±0.18	2.1±0.13	2.7±0.25
56	BRRI dhan33	8.0±0.27	3.0±0.10	2.6±0.00	5.7±0.18	2.6±0.09	2.2±0.10	5.3±0.17	2.5±0.08	2.0±0.12
57	BRRI dhan37	8.5±0.19	2.7±0.08	3.2±0.10	6.0±0.14	2.3±0.06	3.0±0.10	5.5±0.16	1.8±0.07	2.9±0.10
58	BRRI dhan38	8.9±0.22	2.4±0.07	3.7±0.00	6.5±0.16	2.0±0.05	3.2±0.12	6.0±0.20	1.9±0.06	3.1±0.00
59	BRRI dhan40	8.8±0.17	3.2±0.07	2.7±0.10	6.3±0.10	2.8±0.06	2.2±0.06	5.7±0.24	2.7±0.08	2.1±0.15
60	BRRI dhan44	9.1±0.31	3.2±0.10	3.0±0.12	6.4±0.17	2.8±0.06	2.3±0.00	5.9±0.25	2.6±0.10	2.3±0.15
61	BRRI dhan46	8.1±0.17	3.2±0.07	2.6±0.06	5.7±0.12	2.7±0.08	2.1±0.06	5.4±0.18	2.6±0.06	2.0±0.06
62	BRRI dhan49	8.8±0.22	2.4±0.09	3.7±0.26	6.1±0.10	2.0±0.07	3.1±0.17	5.7±0.14	1.9±0.07	3.0±0.20
Range		**7.2-9.1**	**2.1-3.5**	**2.2-4.3**	**5.1-6.5**	**1.8-3.0**	**1.8-3.3**	**5.0-6.0**	**1.6-2.9**	**1.8-3.3**
Mean±SD		**8.3±0.44**	**2.9±0.38**	**3.0±0.48**	**5.9±0.31**	**2.5±0.33**	**2.5±0.38**	**5.5±0.26**	**2.3±0.31**	**2.4±0.35**
CV%		**5**	**13**	**16**	**5**	**13**	**15**	**5**	**13**	**15**
SE (Standard error)		**0.1576**	**0.5498-01**	**0.8267-01**	**0.1038**	**0.4179-01**	**0.6993-01**	**0.1210**	**0.5473-01**	**0.8344-01**
LSD (0.05)		**0.4412**	**0.1539**	**0.2314**	**0.2908**	**0.1169**	**0.1957**	**0.3389**	**0.1532**	**0.2335**

Table-4.2.2c:Variation of length, breadth and L/B ratio associated with paddy, brown rice and milled rice for 31 short grain rice cultivars

Sl.No.	Cultivars	Paddy (L) mm	Paddy(B) mm	Paddy (L/B)	Brown rice (L) mm	Brown rice (B) mm	Brown rice(L/B)	Milled rice (L) mm	Milled rice (B) mm	Milled rice (L/B)
1	Baoijhaki	6.5±0.12	2.7±0.07	2.4±0.06	4.4±0.09	2.3±0.04	1.9±0.06	4.1±0.24	2.1±0.10	1.8±0.10
2	Betudhan	7.5±0.24	3.5±0.09	2.1±0.17	5.3±0.16	2.9±0.13	1.8±0.10	5.0±0.27	2.8±0.12	1.8±0.06
3	Binniphul	6.6±0.15	2.4±0.06	2.7±0.06	4.3±0.07	2.1±0.06	2.0±0.06	4.1±0.35	2.1±0.12	1.7±0.26
4	Chinisagor	6.9±0.21	2.3±0.08	2.9±0.15	4.6±0.14	2.0±0.05	2.3±0.12	4.2±0.19	1.9±0.11	2.2±0.06
5	Chinigura	6.5±0.20	2.4±0.07	2.6±0.06	4.5±0.12	2.0±0.05	2.3±0.15	4.1±0.14	1.9±0.06	2.1±0.06
6	Chunikanai	6.0±0.19	2.2±0.10	2.7±0.15	4.2±0.13	2.0±0.08	2.1±0.00	3.8±0.48	1.9±0.07	1.9±0.10
7	Dudsail	6.6±0.23	2.8±0.05	2.4±0.12	4.4±0.13	2.4±0.04	1.9±0.06	4.0±0.10	2.2±0.05	1.8±0.06
8	Gurdoi	6.1±0.15	2.7±0.07	2.3±0.10	4.2±0.08	2.3±0.04	1.8±0.10	3.9±0.10	2.3±0.08	1.8±0.15
9	Jabsira	7.2±0.23	2.2±0.05	3.2±0.10	5.0±0.09	2.0±0.04	2.5±0.00	4.8±0.24	1.9±0.08	2.5±0.06
10	Jirakatari-1	6.9±0.24	2.2±0.05	3.1±0.10	4.6±0.16	1.9±0.05	2.4±0.06	3.9±0.17	1.7±0.09	2.2±0.06
11	Jirakatari-2	6.7±0.31	2.3±0.08	3.0±0.15	4.7±0.18	2.0±0.03	2.5±0.06	4.1±0.18	1.9±0.05	2.2±0.12
12	Kalasaru	7.6±0.19	2.3±0.07	3.3±0.10	5.4±0.14	2.0±0.04	2.8±0.10	4.8±0.17	1.9±0.06	2.7±0.12
13	Kalijira	6.4±0.16	2.4±0.08	2.8±0.12	4.3±0.08	2.1±0.07	2.1±0.15	3.9±0.09	1.8±0.06	2.1±0.06
14	Khasha	6.0±0.19	2.3±0.04	2.6±0.10	4.0±0.07	2.0±0.02	2.0±0.00	3.7±0.11	1.9±0.09	2.0±0.26
15	Lalsaru	7.1±0.23	2.1±0.08	3.4±0.15	5.1±0.13	1.8±0.06	2.8±0.00	4.5±0.12	1.7±0.06	2.5±0.06
16	Laxmi kajol	6.2±0.21	2.2±0.09	2.9±0.15	4.2±0.11	1.9±0.06	2.2±0.00	3.9±0.12	1.8±0.06	2.1±0.06
17	Malagrosa	6.5±0.19	2.4±0.07	2.7±0.06	4.5±0.12	2.1±0.07	2.2±0.00	4.2±0.11	2.0±0.07	2.0±0.17
18	Michisail	6.5±0.22	2.3±0.07	2.9±0.06	4.2±0.10	1.9±0.07	2.2±0.00	3.9±0.28	1.9±0.12	2.1±0.06
19	Minki	6.8±0.14	3.5±0.09	1.9±0.10	4.7±0.14	3.0±0.04	1.5±0.06	4.3±0.10	2.9±0.10	1.5±0.00
20	Murchmut	6.8±0.16	3.3±0.06	2.1±0.06	4.6±0.15	2.9±0.06	1.6±0.06	4.3±0.18	2.7±0.09	1.6±0.00
21	Nariabochi	7.5±0.21	3.5±0.08	2.2±0.06	5.1±0.15	3.0±0.08	1.8±0.06	4.9±0.14	2.9±0.11	1.6±0.06
22	Nurior	7.0±0.13	3.0±0.07	2.3±0.06	4.9±0.10	2.6±0.05	2.1±0.06	4.4±0.23	2.4±0.09	2.1±0.17
23	Pajam	7.8±0.46	2.5±0.08	3.2±0.17	5.6±0.12	2.2±0.17	2.7±0.06	4.9±0.35	2.0±0.10	2.2±0.35
24	Rahikhama	7.0±0.18	3.0±0.06	2.3±0.06	4.9±0.16	2.6±0.07	2.4±0.15	4.5±0.17	2.3±0.12	2.4±0.12
25	Sorukamina	5.8±0.16	2.3±0.06	2.5±0.06	4.1±0.13	2.0±0.06	2.1±0.06	3.7±0.12	1.9±0.10	2.1±0.17
26	Surjyamukhisangla	6.1±0.17	2.3±0.07	3.0±0.15	4.1±0.12	2.0±0.05	2.2±0.06	3.7±0.16	1.8±0.06	2.0±0.15
27	Topaboro	7.3±0.29	3.2±0.07	2.3±0.10	5.2±0.16	2.6±0.07	1.9±0.00	4.7±0.17	2.5±0.11	1.8±0.15
28	Tulsimala	6.1±0.15	3.1±0.04	2.0±0.00	4.0±0.06	2.7±0.05	1.5±0.00	3.7±0.13	2.5±0.08	1.4±0.00
29	Uknimadhu	6.2±0.13	2.3±0.07	2.7±0.15	4.1±0.08	2.0±0.06	2.0±0.00	4.0±0.73	1.9±0.06	2.0±0.10
30	BR5	6±0.16	2.5±0.06	2.4±0.12	4.2±0.20	2.1±0.06	2.0±0.06	3.8±0.14	2.0±0.06	1.9±0.10
31	BRRI dhan34	6.7±0.13	2.3±0.04	3.0±0.00	4.5±0.11	2.0±0.04	2.3±0.06	4.0±0.10	1.8±0.05	2.2±0.10
Range		**5.8-7.8**	**2.1-3.5**	**1.9-3.4**	**4.0-5.6**	**1.8-3.0**	**1.5-2.8**	**3.7-5.0**	**1.7-2.9**	**1.4-2.7**
Mean±SD		**6.7±0.53**	**2.6±0.44**	**2.6±0.40**	**4.6±0.44**	**2.2±0.36**	**2.1±0.34**	**4.2±0.40**	**2.1±0.35**	**2.0±0.30**
CV%		**8**	**17**	**15**	**10**	**16**	**16**	**10**	**17**	**15**
SE (Standard error)		**0.1229**	**0.4082-01**	**0.6356-01**	**0.7227-01**	**0.3472-01**	**0.4001-01**	**0.1231**	**0.5241-01**	**0.7652-01**
LSD (0.05)		**0.3476**	**0.11548**	**0.1798**	**0.2044**	**0.9822-01**	**0.1131**	**0.3484**	**0.1482**	**0.2164**

Table-4.2.3: The Pearson correlation coefficient forricecultivars at different conditions on the basis of length, breadth and L/B ratio

Correlations

Parameters	**Paddy (L) mm**	**Paddy (B) mm**	**Paddy (L/B) ratio**	**Brown rice (L) mm**	**Brown rice (B) mm**	**Brown rice (L/B) ratio**	**Milled rice (L) mm**	**Milled rice (B) mm**
Paddy (L)mm	1							
Paddy (B) mm	.629	1						
Paddy (L/B) ratio	.993	.529	1					
Brown rice (L) mm	.999*	.655	.988	1				
Brown rice (B) mm	.295	.929	.176	.327	1			
Brown rice (L/B) ratio	.993	.529	1.000**	.988	.176	1		
Milled rice (L) mm	.998*	.672	.984	1.000*	.349	.984	1	
Milled rice (B) mm	.470	.982	.359	.500	.982	.359	.520	1
Milled rice (L/B) ratio	.993	.529	1.000**	.988	.176	1.000**	.984	.359

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

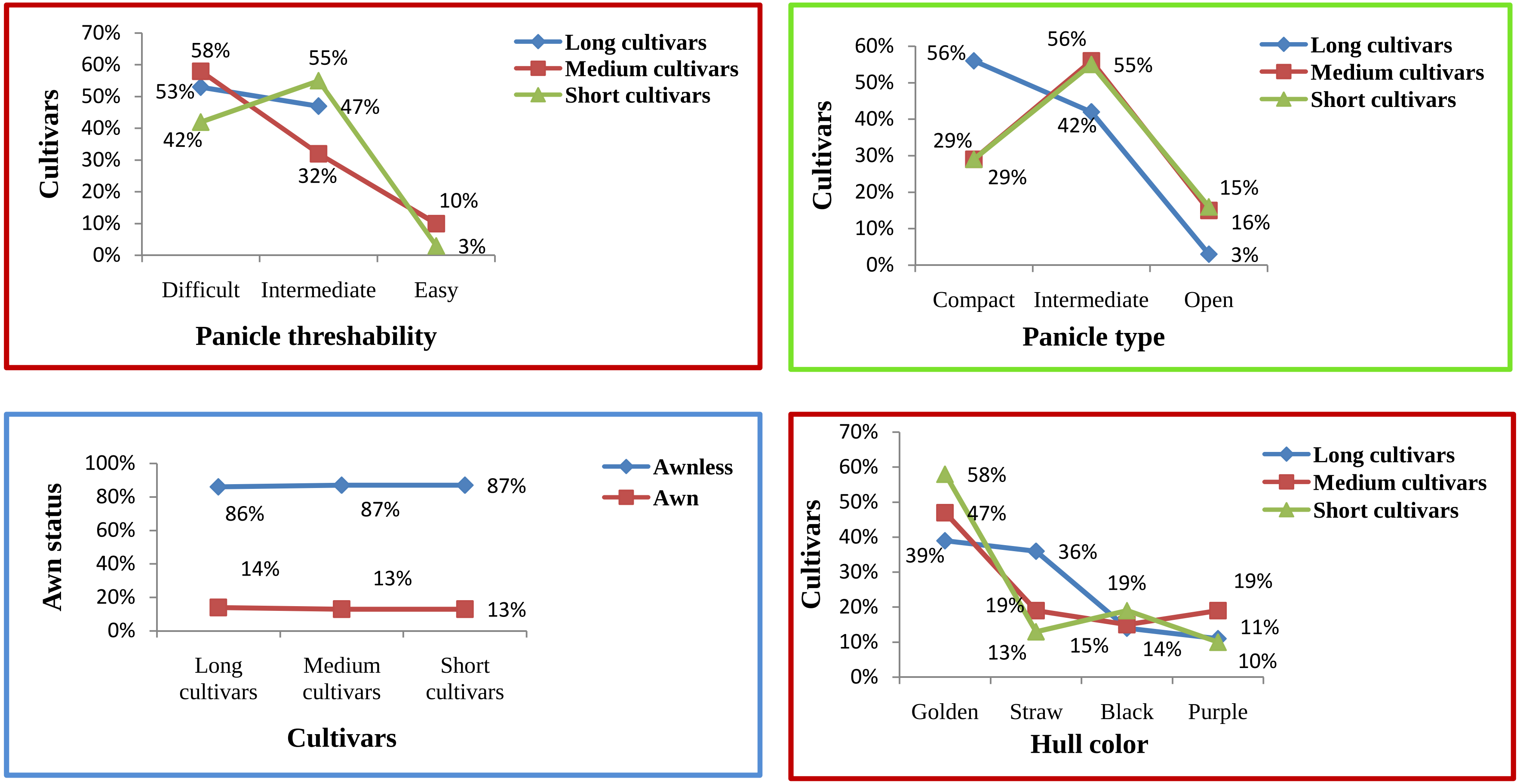

Figure-4.2.1a: Relationship of panicle threshability, panicle type, awn statusand hull color among the long, medium and short grain rice cultivars

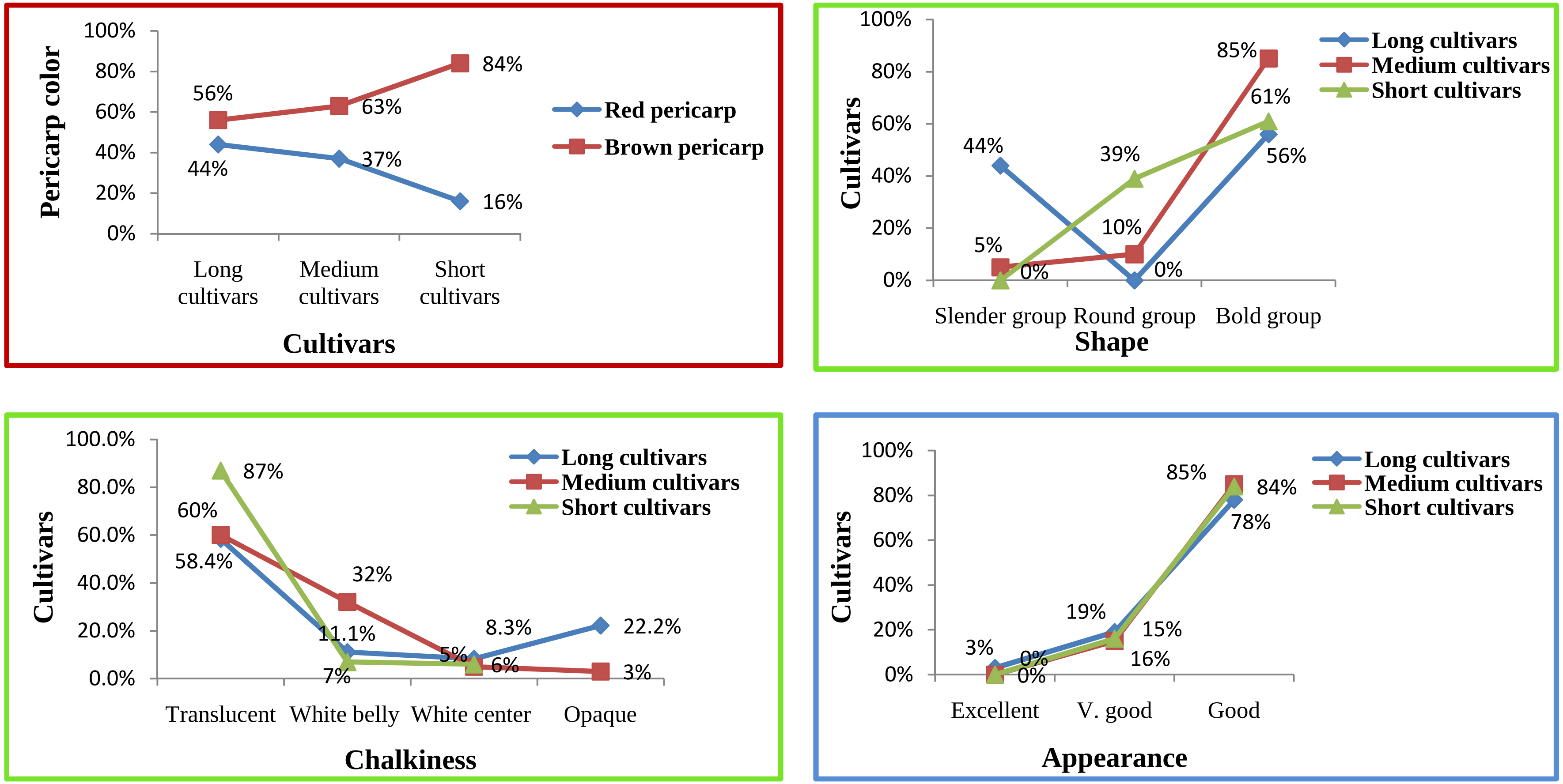

Figure-4.2.1b: Relationship of pericarp color, shape, chalkiness and appearance among the long, medium and short grain rice cultivars

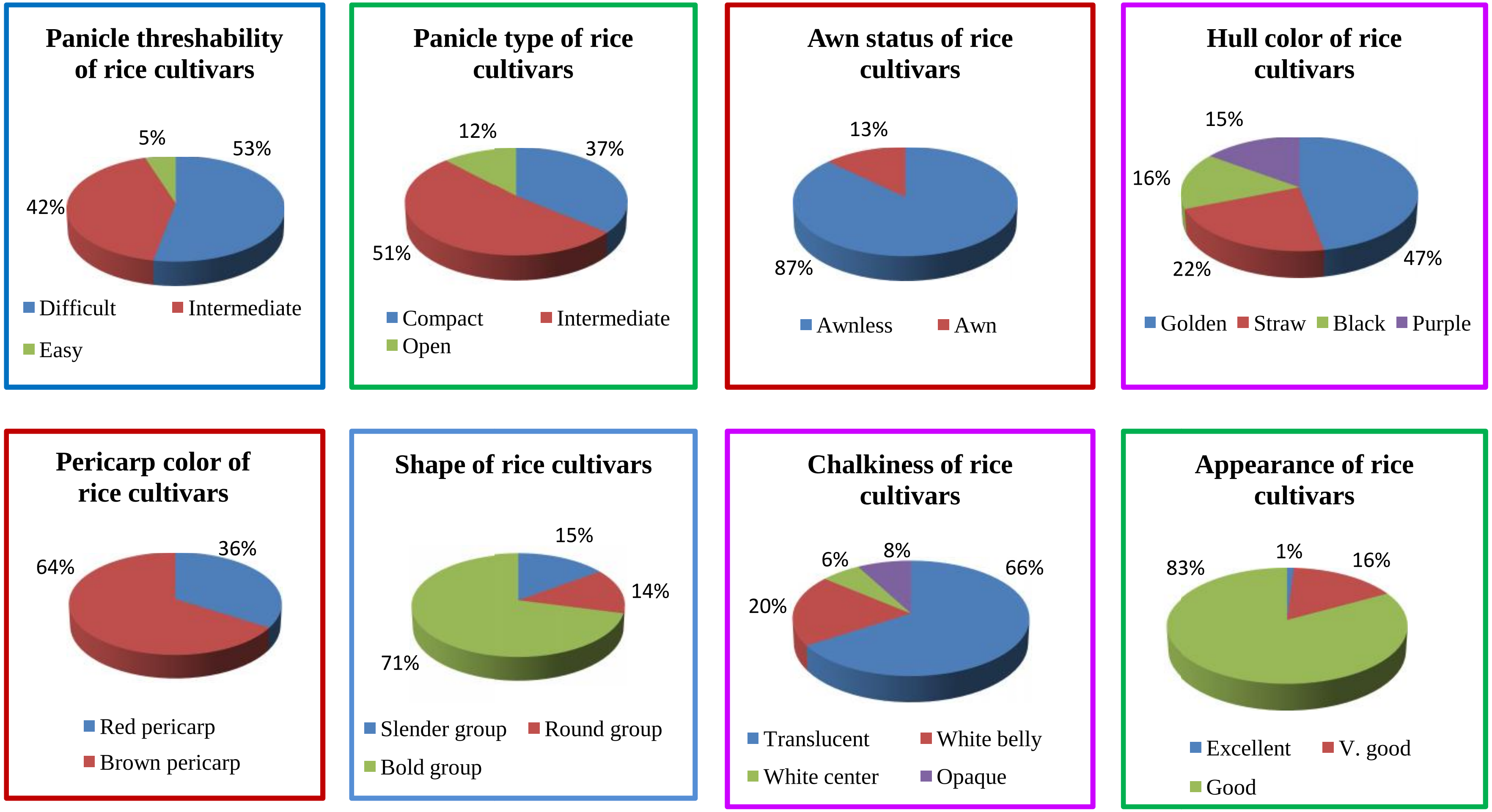

Figure-4.2.2: Frequency distribution of panicle threshability, panicle type, awn status, hull color, pericarp color, shape, chalkiness and appearance for rice cultivars

Figure-4.2.3: Panicle types of different rice cultivars

Figure-4.2.4: Awn status of different rice cultivars

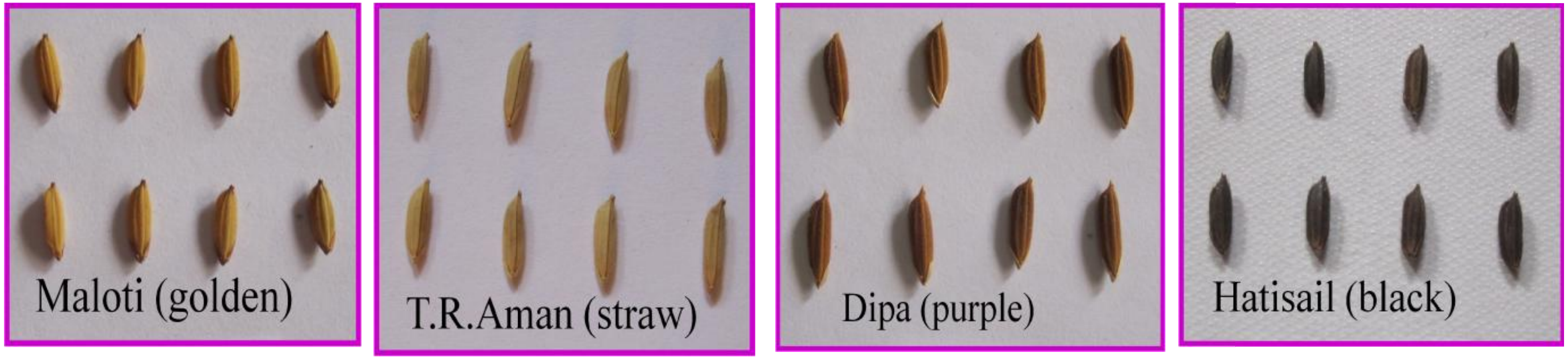

Figure-4.2.5: Hull color of different rice cultivars

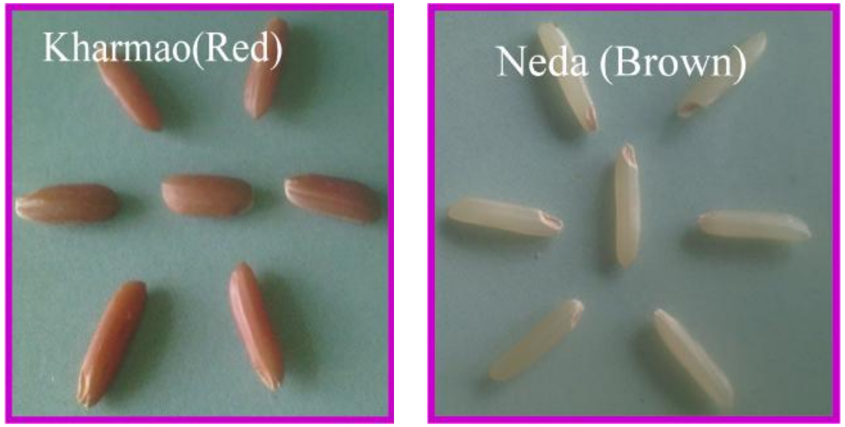

Figure-4.2.6: Pericarp color of rice cultivars

Figure-4.2.7: Chalkiness of rice cultivars

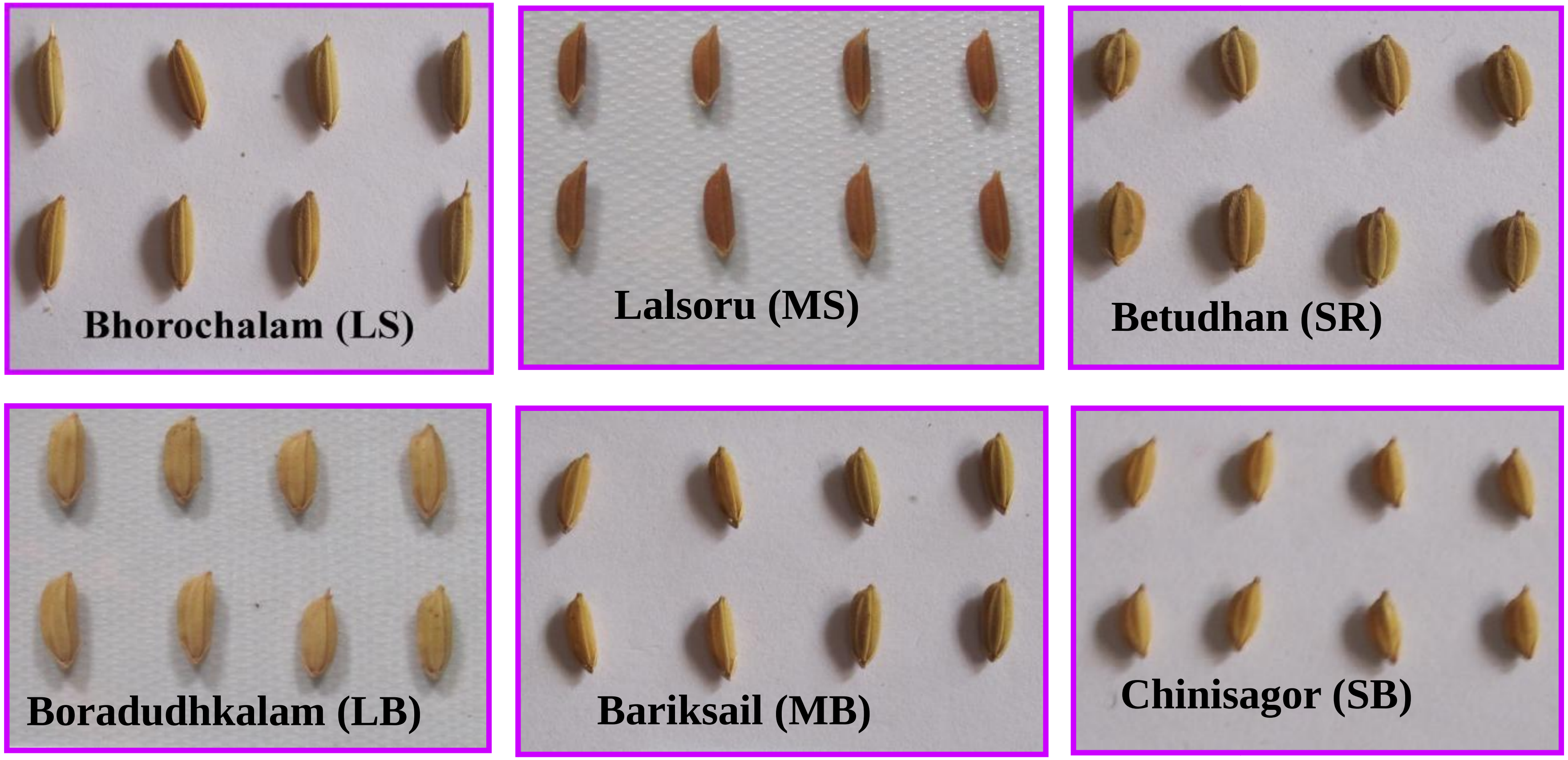

Figure-4.2.8: Size and shape of different rice cultivars

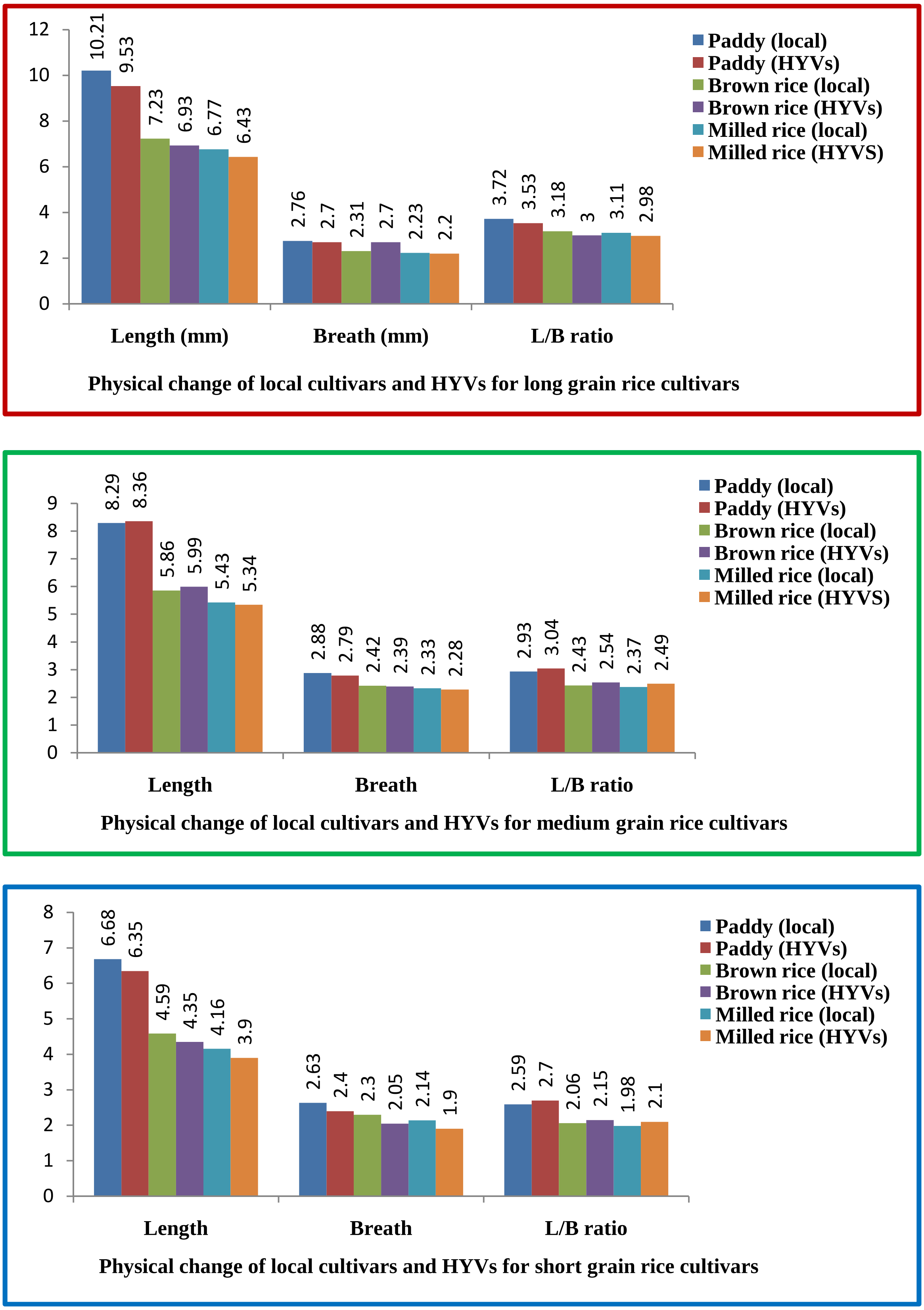

Figure-4.2.9: Comparison of local cultivars with HYVs for long, medium and short grain rice on the basis of physical change

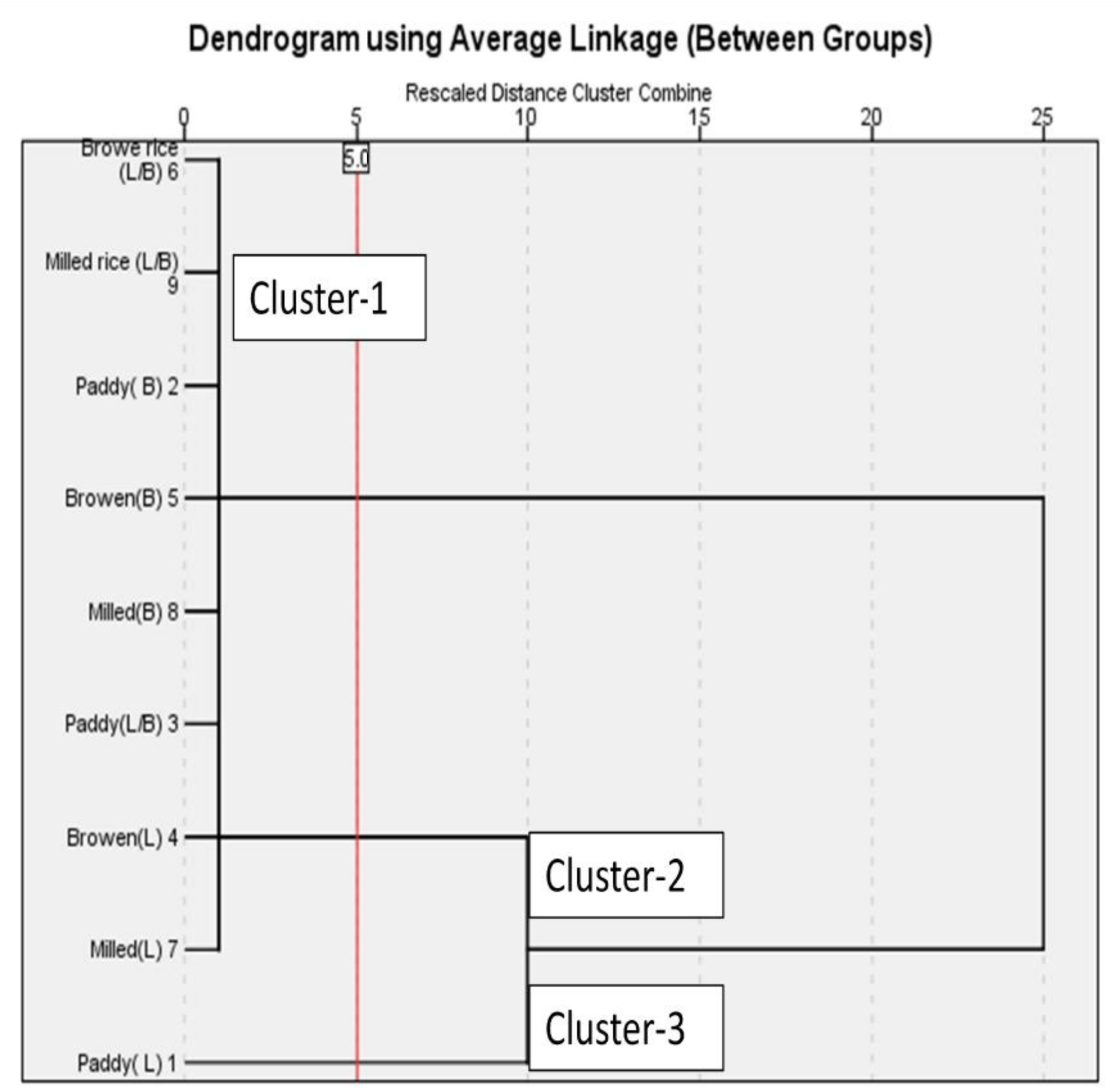

Figure-4.2.10:Dendrogram of all rice cultivars based on length, breadth and L/B ratio of paddy, brown rice and milled rice

4.3: Evaluation of milling and cooking properties for long, medium and short grain rice cultivars

4.3 Milling and cooking properties

In total, 129 rice cultivars including 109 local rice cultivars and 20 HYVs of rice have been evaluated by milling and cooking properties such as milling outturn, head rice recovery, hull content, alkali spreading value, gelatinization temperature, cooking time, elongation ratio, volume expansion ratio and aroma.

4.3.1 Milling outturn

Milling outturn is the total quantity of head rice and broken rice recovered from unit quantity of paddy. The milling outturn of all tested rice cultivars varied from 59% to 74%. Bolonga of medium grain rice cultivar had the highest milling outturn (74%), whereas Chinisagor of short grain rice cultivars had the lowest milling outturn (59%) as same as BRRI dhan46 of the mediumgrain rice cultivars. Out of 129 rice cultivars, 47 had more than 69% milling outturn. Among them 8, 28 and 11 cultivars were long, medium and short grain rice respectively (Table-4.3.1a, Table-4.3.1b and Table-4.3.1c). Milling outturn over 70% is satisfactory for millers and farmers but less than 67% milling outturn is not acceptable.

Milling outturn of long grain rice cultivars varied from 63% to 71% with the mean value of 68±1.76%. Harilaxmi had the highest milling outturn (71%) as like as BRRI dhan39 whereas Kharmao had the lowest milling outturn (63%). Some cultivars such asMolladigha, Dudsar Tapal-146, Binni-1, Binni-2, BRRI dhan30 and BRRI dhan41 had 70% satisfactory milling outturn for millers and farmers.On the other hand, most of the cultivars such as Patnai-231, Boradudhkalam, Bhorochalam, Joalbagh, Redpiebald-219, TK deep straw Tapl-773, Shithabhog, Gohatibinni, Neda, Shata, Pakhisai, Sadajira tapl-321, T.R.Aman, Athabinni, Hatisail, Khorma, Dudhkalam, Depa, Kalimanik, Kalabinni-1, Jingasail-1, Karailadhan,Cylindrical Tapi-629, Jol, Lathamona, Kanaibansi and BR23had the range of milling outturn of (65-69)%. Kharmao of long grain rice cultivar had the lowest milling outturn (63%) with the highest hull content (27%) of its (Table-4.3.1a).

Milling outturn of medium grain rice cultivars varied from 59% to 74% with the mean value of 69±2.47%. Bolonga had the highest milling outturn (74%) but BRRI dhan46 had the lowest milling outturn (59%). Some cultivars such as Lohasail,Hathazi, Lalmota, Changai,BR10, BRRI dhan31, BRRI dhan33, BRRI dhan37, BRRI dhan38, BRRI dhan40 and BRRI dhan49 had desirable milling outturn having the range of milling outturn of (71-73)%. Some other cultivars such as Shamrosh, Bariksail, Tilokkajal, Nizersail, Hijli, Kajalsail, Pakibiroin, Dholagachha, Najirsail, Kanaklata, BR4, BR11, BR22, BR25, BRRI dhan32 and BRRI dhan44had satisfactory milling outturn for millers and farmers (70%). On the other hand, many cultivars such as Kumragoir, Sadamota, Lalbinni, Gojalgoria, Ganjia, Somondori, Maloti, Tilkapur, Poushmoricha, Gobcha, Joyna, Kalisayta, Hashfol, Malsira, Dadkhani, Jhingasail-2, Kataribhog-1, Motichak, Nunia, Kalabinni-2, Rajamora, Chamara, Magoibalam, Ledabinni, Rangabinni, Nakchi, Kataribhog-2, Lalsoru, Paharisail, Boylam, Kataribhog-232, Jhoshua and Putidepahad the range of (64-69)% milling outturn (Table-4.3.1b).

Milling outturn of short grain rice cultivars varied from 59% to 72% with the mean value of 68±2.66%. Nurior and Surjyamukhisangla both had the highest milling outturn (72%) as well as Gurdoi had the second highest (71%), whereas Chinisagor had the lowest milling outturn (59%). Some cultivars such as Malagrosa, Khasha, Chunikanai, Sorukamina, Rahikhama, Dudsail, Topaboro and Pajam had 70% satisfactory milling outturn for millers and farmers. On the other hand, most of the cultivars such as Michisail, Jabsira, Minki, Baoijhaki, Jirakatari-1, Kalijira, Nariabochi, Tulsimala, Jirakatari-2, Binniphul, Laxmikajol, Betudhan, Lalsaru, Uknimadhu, Murchmut, Chinigura, Kalasaru, BR5and BRRI dhan34 had the range of (64-69)% milling outturn (Table-4.3.1c).

Long, medium and short grain local rice cultivars showed similar milling outturn(Figure-4.3.1). Among the rice cultivars, 5.6% long grain, 19.4% medium grain and 10% short grain had at the level of more than 70% milling outturn; 16.7% long grain, 25.8% medium grain and 26% short grain had at the level of 70% milling outturn; 41.7% long grain, 29% medium grain and 35% short grain had at the level of (68-69)% milling outturn as well as 36% long grain, 25.8% medium grain and 29.0% short grain had at the level of less than 68% milling outturn (Figure-4.3.2a).

4.3.2 Head rice recovery

Head rice recovery is the proportion of the whole grain in the milled rice. Head rice recovery of all tested rice cultivars varied from 26%to 98%. Both Dudsail and Chinigura of short grain rice cultivars had the highest head rice recovery (98%) as same as BR25 and BRRI dhan49 of medium grain rice cultivars, whereas Motichak of medium grain rice cultivar had the lowest head rice recovery (26%). Out of 129 rice cultivars,77 had more than

90% head rice recovery. Among them 19, 34 and 24 cultivars werelong, medium and short grain rice respectively (Table-4.3.1a, Table-4.3.1b and Table-4.3.1c).Higher head rice recovery is one of the most important milling quality charactersfor consumers. So, varieties have to be high head rice recovery for commercial success. Head rice recovery depends on varietal characters as well as drying conditions (Wasserman and Calderwood, 1972; Witte, 1972 and Adair *et al*., 1973).

Head rice recovery of long grain rice cultivars varied from 41% to 96% with the mean value of 86±13.07%. Jingasail-1 and Cylindrical Tapi-629 had the highest head rice recovery (96%) as like as BRRI dhan30 and BRRI dhan39, whereas Molladigha had the lowest head rice recovery (41%). Most of the cultivarssuch asAthabinni, Bhorochalam,Harilaxmi,Redpiebald-219, Lathamona, Kalimanik, Binni-1, Gohatibinni, Shata, Hatisail, T.R.Aman, Pakhisail, Binni-2, Khorma, Kanaibansi, Joalbagh, BR23and BRRI dhan41 had the range of head rice recovery of (90-95)%. Some cultivars such as Shithabhog,Dudsar Tapal-146, Patnai-231, Kalabinni-1, Sadajira tapl-321, TK deep straw Tapl-773, Kharmao and Karailadhan had the range of head rice recovery of (80-89)%. Very few cultivars such as Jol, Neda, Depa, Dudhkalam and Boradudhkalam had the range of (51-75)%poor head rice recovery (Table-4.3.1a).

Head rice recovery of medium grain rice cultivars varied from 26% to 98% with the mean value of 87±13.28%. BR25 and BRRI dhan49 had the highest head rice recovery (98%) but Motichak had the lowest head rice recovery (26%). Few cultivars such as Kanaklata, BR22, BRRI dhan32 and BRRI dhan37 had the second highest head rice recovery (97%). Some cultivars such as Nakchi, Paharisail, Hathazi, Kataribhog-2, Sadamota, Bariksail, Nizersail, Kajalsail, Pakibiroin, Bolonga, Najirsail, BR4, BR10,BRRI dhan31 and BRRI dhan38 had the range of head rice recovery of (95-96)%. Some other cultivars such as Kumragoir, Rajamora, Kataribhog-232, Kalabinni-2, Lalsoru, Ganjia, Somondori, Hijli, Dadkhani, Maloti, Tilokkajal, Lohasail, Kataribhog-1, Rangabinni,BR11 and BRRI dhan40had the range of head rice recovery of (90-94)%. Many cultivars such as Nunia, Jhoshua, Gobcha, Putidepa, Changai, Lalmota, Malsira, Chamara, Dholagachha, Joyna, Hashfol, Lalbinni, Tilkapur, Poushmoricha, Ledabinni, Jhingasail-2,BRRI dhan33, BRRI dhan44 and BRRI dhan46 had the range of head rice recovery of (70-89)%. But other few cultivars such as Shamrosh, Magoibalam, Kalisayta, Gojalgoria and Boylam had the range of (44-67)%very poor head rice recovery (Table-4.3.1b).

Head rice recovery of short grain rice cultivars varied from 75% to 98% with the mean value of 93±6.08%. Dudsail and Chinigura had the highest head rice recovery (98%) but Kalasaru had the lowest head rice recovery (75%). Most of the cultivars such as Binniphul, Chunikanai, Sorukamina, Nurior, Gurdoi, Lalsaru, Surjyamukhisangla, Jirakatari-2, Kalijira, Pajam, Uknimadhu, Malagrosa, Khasha, BR5 and BRRI dhan34 had the range of head rice recovery of (95-97)%. Some cultivars such as Chinisagor, Jabsira, Topaboro, Baoijhaki, Jirakatari-1, Michisail and Minki had the range of head rice recovery of (92-94)%. On the other hand, some other cultivars such as Tulsimala, Betudhan, Rahikhama, Murchmut, Laxmikajol and Nariabochi had the range of (76-89)% head rice recovery (Table-4.3.1c).

The highest head rice recovery was found in short grain local rice cultivars followed by long grain but the lowest one was in medium grain local rice cultivars (Figure-4.3.1). Among the rice cultivars, 6.3% long grain, 17.7% medium grain and 48.4% short grain had at the level of more than 95% head rice recovery; 50% long grain, 41.9% medium grain and 29% short grain had at the level of (90-95)% head rice recovery; 22.2% long grain, 24.2% medium grain and 16.1% short grain had at the level of (80-89)% head rice recovery; 5.6% long grain, 6.5% both medium and short grain had at the level of (70-79)% head rice recovery as well as 11.1% long grain and 9.7% medium grain had at the level of less than 70% head rice recovery (Figure-4.3.2a).

4.3.3 Hull content

Hull of rough rice, which is composedof two modified tough leaves lemma and palea, encloses brown rice. Hull content of all rice cultivars varied from 19% to 27%. Kharmao of long grain rice cultivar had the highest hull content (27%) butBRRI dhan31 of medium grain rice cultivar had the lowest hull content (19%).Milling outturn varied depending on the hull content of the rice cultivars. Higher weight of the hull lowers the milling outturn of the rice. Kharmao of long grain rice cultivar had the lowest milling outturn (63%) with the highest hull content (27%) of its. So, hull content of paddy influences the milling outturn of paddy. Out of 129 rice cultivars, 24had lower hull contenthaving the range of (19-21)%. Among them 4, 16 and 4 cultivars were long, medium and short grain rice respectively (Table-4.3.1a, Table-4.3.1b and Table-4.3.1c).

Hull content of long grain rice cultivars varied from 21% to 27% with the mean value of 23±1.57%. Kharmao had the highest hull content (27%) but Boradudhkalam, Dudsar Tapal-146 and Nedahad the lowest hull content (21%) as same as BRRI dhan39.Cultivars of

Jingasail-1 and Kanaibansi had the second highest hull content (26%). Some cultivars such as Hatisail, Khorma, Cylindrical Tapi-629, Jol, Kalimanik, Patnai-231, Karailadhan, Lathamona, Pakhisail and Binni-1 had the range of hull content of (24-25)%.Most of the cultivars such as Bhorochalam, Joalbagh, T.R.Aman, Sadajira tapl-321, Shithabhog, Kalabinni-1, Athabinni, Gohatibinni, Binni-2, Dudhkalam, Depa, Molladigha, Redpiebald-219, TK deep straw Tapl-773, Harilaxmi, Shata, BR23, BRRI dhan30 and BRRI dhan41had the range of (22-23)% hull content (Table-4.3.1a).

Hull content of medium grain rice cultivars varied from 19% to 26% with the mean value of 23±1.64%. Few rice cultivars such as Jhoshua, Putidepa, Chamara and Magoibalam had the highest hull content (26%) but BRRI dhan31 had the lowest hull content (19%). Some cultivars such as Rangabinni, Kataribhog-1, Paharisail, Boylam, Nunia, Rajamora,Kalabinni-2, Hijli, Ledabinni, Motichak, Kalisayta and Kataribhog-232 had the range of hull content of (24-25)%. Most of the cultivars such as Nakchi, Hashfol, Lalbinni, Lalsoru, Gojalgoria, Somondori, Maloti, Bariksail, Nizersail, Tilkapur, Gobcha, Dadkhani, Joyna, Najirsail, Kanaklata, Lohasail, Sadamota, Shamrosh, Ganjia, Malsira, Pakibiroin, Dholagachha, Poushmoricha, Jhingasai-2, BR4, BR10, BR22, BR25, BRRI dhan32 andBRRI dhan49 had the range of hull content of (22-23)%. But some other cultivars such as Kumragoir, Tilokkajal, Kajalsail, Changai, Lalmota, Hathazi, Bolonga, Kataribhog-2, BR11, BRRI dhan33, BRRI dhan37, BRRI dhan38, BRRI dhan40, BRRI dhan44 and BRRI dhan46 had the range of (20-21)% hull content (Table-4.3.1b).

Hull content of short grain rice cultivars varied from 20% to 26% with the mean value of 23±1.43%. Uknimadhu had the highesthull content (26%) but Chunikanai had the lowest hull content (20%). Most of the cultivars such as Betudhan, Binniphul, Tulsimala, Murchmut, Kalasaru, Chinisagor, Gurdoi, Minki, Pajam, Laxmikajol, Jirakatari-1,Topaboro,Jirakatari-2 and BR5 had the range of hull content of (23-25)%. Some cultivars such as Malagrosa, Nariabochi, Michisail, Jabsira, Khasha, Rahikhama, Nurior, Lalsaru, Baoijhaki, Dudsail, Chinigura andKalijira had 22% hull content. Few cultivars such as Sorukamina, Surjyamukhisangla and BRRI dhan34had 21% hull content (Table-4.3.1c).

The highest hull content was found in long grain local rice cultivars but the lowest one was in both medium and short grain local rice cultivars (Figure-4.3.1). Among the rice cultivars, 25% long grain, 13% medium grain and 19.4% short grain had at the level of more than 25% hull content; 75% long grain, 77% medium grain and 77.4% short grain had at the level of (21-24)% hull content as well as only 10% medium grain and 3.2%short grain had at the level of less than 20% hull content (Figure-4.3.2a).

4.3.4 Alkali spreading value

High alkali spreading value corresponds to low gelatinization temperature. Alkali spreading value (ASV) of all rice cultivars varied from 3.2 to 7.0. Cylindrical Tapi-629 of long grain and Rangabinni of medium grain rice cultivars had the highest alkali spreading value (7) but Kanaibansi of long grain rice cultivar had the lowest alkali spreading value (3.2). Out of 129 rice cultivars, 82 had less than 5.5 alkali spreading value. Among them 20, 39 and 23 cultivars were long, medium and short grain rice respectively (Table-4.3.1a, Table-4.3.1b and Table-4.3.1c).

Alkali spreading value of long grain rice cultivars varied from 3.2 to 7.0 with the mean value of 5.2±0.95. Cylindrical Tapi-629 had the highest alkali spreading value (7) but Kanaibansi had the lowest alkali spreading value (3.2). Most of the cultivars such as Gohatibinni, Athabinni, Kalabinni-1, Lathamona, Binni-1, Hatisail, T.R.Aman, TK deep straw Tapl-773, Kalimanik, Patnai-231, Redpiebald-219, Sadajira tapl-321, BRRI dhan30, BRRI dhan39 and BRRI dhan41 had the range of alkali spreading value of (5.5-6.7). On the other hand, other cultivars such as Shithabhog, Shata, Bhorochalam, Pakhisail, Boradudhkalam, Binni-2, Dudsar Tapal-146, Depa, Dudhkalam, Joalbagh, Harilaxmi, Jingasail-1, Neda, Karailadhan, Khorma, Kharmao, Molladigha, Jol and BR23 had the range of (3.5-5.4) alkali spreading value (Table-4.3.1a).

Alkali spreading value of medium grain rice cultivars varied from 3.8 to 7.0 with the mean value of 5.2±0.76. Rangabinni had the highest alkali spreading value (7.0) but both Boylam and Magoibalam had the lowest alkali spreading value (3.8). Some cultivars such as Nakchi, Sadamota, Lalmota, Ganjia, Hijli, Maloti, Bariksail, Ledabinni, Joyna, Kataribhog-2, Lohasail, Najirsail, Somondori, BR4, BR11, BR22, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan44, BRRI dhan37 and BRRI dhan38 had the range of alkali spreading value of (5.5-6.8). But many cultivars such as Changai, Lalsoru, Dadkhani, Nunia, Jhoshua, Paharisail, Tilokkajal, Shamrosh, Kataribhog-232, Motichak, Putidepa, Chamara, Rajamora, Kataribhog-1, Hathazi, Gojalgoria, Nizersail, Tilkapur, Hashfol, Kalabinni-2, Malsira, Pakibiroin, Dholagachha, Kanaklata, Kajalsail, Poushmoricha, Kalisayta, Kumragoir, Jhingasail-2, Bolonga, Lalbinni, Gobcha, BR10, BR25, BRRI dhan33, BRRI dhan46 and BRRI dhan49 had the range of (4.0-5.4) alkali spreading value (Table-4.3.1b).

Alkali spreading value of short grain rice cultivars varied from 3.7 to 6.4 with the mean value of 4.9±0.75. Murchmut had the highest alkali spreading value (6.4) but Uknimadhu had the lowest alkali spreading value (3.7). Some cultivars such as Minki, Tulsimala, Binniphul, Chinigura, Kalijira, Nariabochi and Gurdoi had the range of alkali spreading valueof (5.5-6.4). But most of the cultivars such as Nurior, Lalsaru, Dudsail, Surjyamukhisangla, Rahikhama, Betudhan, Michisail, Baoijhaki, Chunikanai, Topaboro, Jabsira, Pajam, Sorukamina, Kalasaru, Jirakatari-1, Malagrosa, Chinisagor, Laxmikajol, Jirakatari-2, Khasha, BR5 and BRRI dhan34 had the range of (3.9-5.4) alkali spreading value (Table-4.3.1c).

The highest alkali spreading value was found in short grain local rice cultivars followed by medium grain but the lowest one was in long grain local rice cultivars at the level of <5.5 (Figure-4.3.1). Among the rice cultivars, 28% long grain, 15% medium grain and 13% short grain had at the level of (6-7) of alkali spreading value; 42% long grain, 47% medium grain and 32% short grain had at the level of (5-6) of alkali spreading value; 19% long grain, 35% medium grain and 48% short grain had at the level of (4-5) of alkali spreading value as well as 11% long grain, 3% medium grain and 7% short grain had at the level of less than 4 alkali spreading value (Figure-4.3.2b).

4.3.5 Gelatinization temperature

Gelatinization temperature is the temperature in which the starch granules of rice grain begin to swell irreversible in hot water. Time required for cooking is determined by the gelatinization temperature. Out of 129 rice cultivars, 82 had intermediate and 47 had low gelatinization temperature. So, intermediate gelatinization temperature had higher than the low gelatinization temperature among the rice cultivars (Table-4.3.1a, Table-4.3.1b and Table-4.3.1c). There was no cultivar with high gelatinization temperature among the rice cultivars. Fine grain rice having intermediate gelatinization temperature produces good quality cooked rice.

Among the long grain rice cultivars, 20 had intermediate and 16 had low gelatinization temperature (Table-4.3.1a). Among the medium grain rice cultivars, 39 had intermediate and 23 had low gelatinization temperature (Table-4.3.1b). Among the short grain rice cultivars, 23 had intermediate and 8 had low gelatinization temperature (Table-4.3.1c).The highest intermediate gelatinization temperature was found in short grain local rice cultivars followed by medium grain but the lowest one was in long grain local rice cultivars (Figure-4.3.1). Among the rice cultivars, 56% long grain, 63% medium grain and 74% short grain had intermediate gelatinization temperature as well as 44% long grain, 37% medium grain and 26% short grain had low gelatinization temperature(Figure-4.3.2b).

4.3.6 Cooking time

Cooking time of rice is important for consumer due to energy saving of fuel. During cooking disappeared starch granules of rice with time is called cooking time. In cooked rice kernel 90% starch granules disappeared (Figure-4.3.3). The change of optimum cooking time depends on rice cultivars. Cooking time of all rice cultivars varied from 13 minutes to 23 minutes. Both Jol and Molladigha of long grain, Kalisayta of medium grain as well as Nurior of short grain rice cultivars had the highest cooking time (23 minutes). Lalsoru of medium grain as well as Khasha, Jirakatari-2, BR5 and BRRI dhan34 of short grain rice cultivars had the lowest cooking time (13 minutes). Out of 129 rice cultivars, 28 had less than 16 minutes cooking time. Among them 2, 8 and 18 cultivars were long, medium and short grain rice respectively (Table-4.3.1a, Table-4.3.1b and Table-4.3.1c).

Cooking time of long grain rice cultivars varied from 15 minutes to 23 minutes with the mean value of 18±1.87 minutes. Both Jol and Molladigha had the highest cooking time (23 minutes) whereas both Gohatibinni and Karailadhan had the lowest cooking time (15 minutes). Boradudhkalam and Harilaxmi had 21 and 20 minutes cooking time respectively. Most of the cultivars such as Bhorochalam, Dudsar Tapal-146, Dudhkalam, Depa, Joalbagh, Jingasail-1, Neda, Shithabhog, Binni-2, Hatisail, Kharmao, Kalimanik, Pakhisail, Redpiebald-219, BRRI dhan30 and BRRI dhan39 had the range of cooking time of (18-19) minutes. On the other hand, other cultivars such as Kanaibansi, Khorma, Patnai-231, T.R.Aman, TK deep straw Tapl-773, Binni-1, Cylindrical Tapi-629, Shata, Athabinni, Kalabinni-1, Lathamona, Sadajira tapl-321, BR23 and BRRI dhan41 had the range of cooking time of (16-17) minutes (Table-4.3.1a).

Cooking time of medium grain rice cultivars varied from 13 minutes to 23 minutes with the mean value of 18±2.57 minutes. Kalisayta had the highest cooking time (23 minutes) but Lalsoru had the lowest cooking time (13 minutes). Some cultivars such as Kumragoir, Pakibiroin, Dholagachha, Boylam, Motichak, Lalmota, Magoibalam, Jhingasail-2, Hathazi, Hashfol, Tilokkajal, Chamara, Kajalsail, Gobcha, Joyna, Changai, BRRI dhan31, BRRI dhan33, BRRI dhan40 and BRRI dhan44 had the range of cooking time of (20-22) minutes. Most of the cultivars such as Nakchi, Sadamota, Rajamora, Bolonga, Lohasail, Shamrosh,Kalabinni-2, Gojalgoria, Paharisail, Malsira, Hijli, Poushmoricha, Lalbinni, Putidepa, Bariksail, Tilkapur, Dadkhani, Nunia, Jhoshua, Somondori, Nizersail, Ledabinni, Rangabinni, Najirsail, BR4, BR10, BR11, BR22, BR25, BRRI dhan32, BRRI dhan38, BRRI dhan46 and BRRI dhan49 had the range of cooking time of (16-19) minutes. Few cultivars such as Ganjia, Kataribhog-232, Kataribhog-1, Kanaklata, Kataribhog-2, Maloti and BRRI dhan37 had the range of cooking time of (14-15) minutes (Table-4.3.1b).

Cooking time of short grain rice cultivars varied from 13minutes to 23 minutes with the mean value of 16±2.87minutes.Nurior had the highest cooking time (23 minutes) whereas Khasha and Jirakatari-2 had the lowest cooking time (13 minutes) as same as BR5 and BRRI dhan34. Rahikhama had 22 minutes cooking time as well asMinki and Topaboro both had 21 minutes cooking time. Somecultivars such asNariabochi, Betudhan, Tulsimala, Gurdoi, Pajam, Murchmut,Binniphul, Baoijhaki, Dudsailand Kalasaruhad the range of cooking time of (16-18) minutes. On the other hand, many cultivars such as Chinisagor, Chinigura, Chunikanai, Jabsira, Jirakatari-1, Kalijira, Kalasaru,Lalsaru, Laxmikajol, Malagrosa, Michisail, Sorukamina, Surjyamukhisangla and Uknimadhu had 14 minutes cooking time (Table-4.3.1c).

The highest cooking time was found in medium grain local rice cultivars followed by long grain but the lowest one was in short grain local rice cultivars (Figure-4.3.1). Among the rice cultivars, 11% long grain, 34% medium grain and 13% short grain had at the level of more than 20 minutes cooking time; 83% long grain, 53% medium grain and 29% short grain had at the level of (16-19) minutes cooking time as well as 6% long grain, 13% medium grain and 58% short grain had at the level of less than 15 minutes cooking time (Figure-4.3.2b).

4.3.7 Elongation ratio

Lengthwise increase without an increase in girthwise is considered as highly desirable trait for premium quality rice cultivars. Elongation ratio of all rice cultivars varied from 1.5 to 2.3. Short grain rice cultivars of Chunikanai, Lalsaru and Surjyamukhisangla had the highest elongation ratio (2.3). But Jingasail-1 and Gohatibinni of long grain as well as Lalsoru, Magoibalam, Ledabinni and Kataribhog-232 of medium grain rice cultivars had the lowest elongation ratio (1.5). Out of 129 rice cultivars, 45 had the range of elongation ratio of (2.0-2.3). Among them 2, 22 and 21cultivars were long, medium and short grain rice respectively (Table-4.3.1a, Table-4.3.1b and Table-4.3.1c). Formation of transverse cracks during presoaking improves grain elongation during cooking. Some milled rice had extreme elongation when cooked, especially after presoaking.

Elongation ratio of long grain rice cultivars varied from 1.5 to 2.0 with the mean value of 1.7±0.13. Cultivars of T.R.Aman and Molladigha had the highest elongation ratio (2) whereas Gohatibinniand Jingasail-1 had the lowest elongation ratio (1.5). Most of the cultivars such as Boradudhkalam, Depa, Joalbagh, Jol, Harilaxmi, Patnai-231, Hatisail,Dudsar Tapal-146, Sadajira tapl-321, Cylindrical Tapi-629, Lathamona, Shithabhog, Kalabinni-1, BRRI dhan30, BRRI dhan39and BRRI dhan41 had the range of elongation ratio of (1.8-1.9).On the other hand, other cultivarssuch as Dudhkalam, Kharmao, Redpiebald-219, TK deep straw Tapl-773, Karailadhan, Pakhisail, Binni-1, Neda, Khorma, Kanaibansi, Bhorochalam, Kalimanik, Athabinni, Shata, Binni-2 and BR23 had the range of (1.6-1.7)elongation ratio (Table-4.3.1a).

Elongation ratio of medium grain rice cultivars varied from 1.5 to 2.2 with the mean value of 1.9±0.19. Cultivars of Sadamota, Ganjia, Maloti and Jhingasail-2 had the highest elongation ratio (2.2)whereasLalsoru, Magoibalam, Ledabinni and Kataribhog-232 had the lowest elongation ratio (1.5). Many cultivars such as Lohasail, Hashfol, Shamrosh, Somondori, Nizersail, Najirsail, Nakchi, Kumragoir, Lalbinni, Putidepa, Tilokkajal, Poushmoricha, Changai, Kataribhog-2, Lalmota, Kanaklata, BRRI dhan32 and BRRI dhan33 had the range of elongation ratio of (2.0-2.1). Most of thecultivarssuch asNunia, Gojalgoria, Bariksail, Chamara, Tilkapur, Dholagachha, Hathazi, Gobcha, Kataribhog-1, Paharisail,Kalabinni-2, Rajamora, Kajalsail, Dadkhani, BR4, BR22,BRRI dhan37, BRRI dhan38, BRRI dhan40, BRRI dhan44, BRRI dhan46 and BRRI dhan49 had the range of elongation ratio of (1.8-1.9). But, rest of the cultivars such as Malsira, Hijli, Pakibiroin, Bolonga, Joyna, Boylam, Motichak, Kalisayta, Jhoshua, Rangabinni, BR10, BR11, BR25 andBRRI dhan31 had the range of (1.6-1.7)elongation ratio (Table-4.3.1b).

Elongation ratio of short grain rice cultivars varied from 1.8 to 2.3 with the mean value of 2.0±0.15. Cultivars of Chunikanai, Lalsaru and Surjyamukhisangla had the highest elongation ratio (2.3)whereas Nariabochi, Nurior, Laxmikajol and Jirakatari-1 had the lowest elongation ratio (1.8). Most of the cultivars such as Uknimadhu, Malagrosa, Khasha, Baoijhaki, Murchmut, Sorukamina, Minki, Dudsail, Chinigura, Kalijira, Chinisagor, Binniphul, Tulsimala, Rahikhama, Gurdoi, Pajam, BR5 and BRRI dhan34 had the range of elongation ratio of (2.0-2.2). But few cultivarssuch as Betudhan, Michisail, Jabsira, Kalasaru, Jirakatari-2 and Topaboro had 1.9 elongation ratio (Table-4.3.1c).

The highest elongation ratiowas found in short grain local rice cultivars followed by medium grain but the lowest one was in long grain local rice cultivars (Figure-4.3.1). Among the rice cultivars, 18% medium grain and 48.4% short grain had at the level of more than 2elongationratio; 6% long grain, 18% medium grain and 19.3% short grain had at the level of 2elongationratio; 44% long grain, 35% medium grain and 32.3% short grain had at the level of (1.8-1.9) elongationratio; 44% long grain, 23% medium grain and no short grain had at the level of (1.6-1.7) elongation ratio as well as 6% long grain, 6% medium grain and no short grain had at the level of less than 1.6 elongation ratio (Figure-4.3.2c).

4.3.8 Volume expansion ratio

Volume expansion ratio is another preferable quality for evaluation of cooking quality. Most of the people in Bangladesh generally prefer rice cultivars with high volume expansion.Volume expansion ratio of all tested rice cultivars varied from3.1 to 4.3. Hashfol of medium grain rice cultivarhad the highest volume expansion ratio (4.3) whereas Athabinni, Kalabinni-1 and Gohatibinni of long grain as well as Rangabinni of medium grain rice cultivars had the lowest volume expansion ratio (3.1). Out of 129 rice cultivars, 23had the range of volume expansion ratio of (4.0-4.3). Among them 3, 15 and 5 cultivars were long, medium and short grain rice respectively (Table-4.3.1a, Table-4.3.1b and Table-4.3.1c). Volume expansion ratioof less than 3.5 is undesirable trait.

Volume expansion ratio of long grain rice cultivars varied from 3.1 to 4.0 with the mean value of 3.6±0.24. Molladigha had the highest volume expansion ratio (4.0) as same as BRRI dhan30 and BRRI dhan39 whereas Kalabinni-1, Athabinni and Gohatibinni had the lowest volume expansion ratio (3.1). Most of the cultivars such as Kharmao, Joalbagh, Neda, Jol, Khorma, Boradudhkalam, Kanaibansi, Dudsar Tapal-146, Karailadhan, Depa, Harilaxmi, TK deep straw Tapl-773, Kalimanik, Lathamona, Pakhisail, Hatisail, Bhorochalam, T.R.Aman, Redpiebald-219, Sadajira tapl-321, Shata, Binni-2,Shithabhog,BR23 and BRRI dhan41 had the range of volume expansion ratio of (3.6-3.9). But few cultivars such as Patnai-231, Jingasail-1, Cylindrical Tapi-629, Binni-1 and Dudhkalamhad the range of (3.3-3.4) volume expansion ratio (Table-4.3.1a).

Volume expansion ratio of medium grain rice cultivars varied from 3.1 to 4.3 with the mean value of 3.7±0.23. Hashfol had the highest volume expansion ratio (4.3) but Rangabinni had the lowest volume expansion ratio (3.1). Some cultivars such as Kumragoir, Shamrosh, Bariksail, Bolonga, Jhingasail-2, Kataribhog-232, Dadkhani, Najirsai,BR4, BR10, BR22, BRRI dhan33, BRRI dhan40 and BRRI dhan49 had the second highest volume expansion ratio (4.0). Most of the cultivarssuch as Lohasail, Kataribhog-1, Nunia, Gojalgoria, Joyna, Lalmota, Kanaklata, Nakchi, Paharisail, Kalabinni-2, Lalsoru, Nizersail, Rajamora, Chamara, Tilkapur, Hijli, Changai, Kalisayta, Lalbinni, Ganjia, Jhoshua, Malsira, Somondori, Kataribhog-2, Dholagachha, Poushmoricha, Boylam, Maloti, Hathazi, BR11, BR25, BRRI dhan31,BRRI dhan32, BRRI dhan37, BRRI dhan38, BRRI dhan44 and BRRI dhan46 had the range of volume expansion ratio of (3.6-3.9). But, rest of the cultivars such as Sadamota, Putidepa, Tilokkajal, Kajalsail, Magoibalam, Pakibiroin, Ledabinni, Motichak and Gobcha had the range of (3.3-3.4)volume expansion ratio (Table-4.3.1b).

Volume expansion ratio of short grain rice cultivars varied from 3.4 to 4.0 with the mean value of 3.8±0.20. Cultivars of Chunikanai, Gurdoi and Pajam had the highest volume expansion ratio (4.0) as same as BR5 and BRRI dhan34 whereas Chinisagor, Nariabochi, Binniphul, Murchmut and Minki had the lowest volume expansion ratio (3.4). Most of the cultivars such as Uknimadhu, Michisail, Jabsira, Sorukamina, Lalsaru, Baoijhaki, Chinigura, Surjyamukhisangla, Jirakatari-2, Kalijira, Khasha, Nurior, Kalasaru, Dudsail, Topaboro, Jirakatari-1, Malagrosa, Betudhan, Tulsimala, Rahikhama and Laxmikajol had the range of (3.6-3.9) volume expansion ratio (Table-4.3.1c).

The highest volume expansion ratio was found in medium grain local rice cultivars followed by short grain but the lowest one was in long grain local rice cultivars (Figure-4.3.1). Among the rice cultivars, 8.3% long grain, 24% medium grain and 16% short grain had at the level of more than 3.9 volume expansion ratio; 69.5% long grain, 58% medium grain and 68% short grain had at the level of volume expansion ratio of (3.6-3.9) as well as 22.2% long grain, 18% medium grain and 16% short grain had at the level of less than 3.6 volume expansion ratio (Figure-4.3.2c).

4.3.9 Aroma

Presence of aroma in the rice is another desirable trait for cooking quality. Out of 129 rice cultivars, 24 had aroma. Jingasail-1and Hatisail of long grain had aroma. Some cultivars such as Jhingasail-2, Kataribhog-1, Kataribhog-2, Lalsoru, Maloti and Nuniaofmedium grain had aroma. But, most of the cultivars such as Baoijhaki, Chinisagor, Chinigura, Jabsira, Jirakatari-1, Kalasaru, Jirakatari-2, Kalijira, Khasha, Nurior, Sorukamina,Topaboro, Tulsimala, Uknimadhu, BR5 and BRRI dhan34ofshort grainhad aroma. (Table-4.3.1a, Table-4.3.1b and Table-4.3.1c). The highest number of aromatic rice was found in short grain local rice cultivars followed by medium grain but the lowest one was in long grain local rice cultivars (Figure-4.3.1). Among the rice cultivars, 6% long grain, 10% medium grain and 52% short grain had aroma but 94% long grain, 90% medium grain and 48% short grain had no aroma (Figure-4.3.2c).

4.3.10 Correlation of milling and cooking properties

Pearson correlation coefficients for relationships had among various milling and cooking parameters of different long grain rice cultivars. In long grain rice cultivars, elongation ratio as well as volume expansion ratio were highly significant and positively correlated with cooking time (r=0.459, r=0.591, p<0.01). Alkali spreading value as well as hull content both were significant and positively correlated with head rice recovery (r=0.445, r=0.409, p<0.05). Volume expansion ratio was significant and positively correlated with elongation ratio (r=0.389, p<0.05). Elongation ratio was significant and negatively correlated with head rice recovery (r= -0.436, p<0.05). Hull content was highly significant and negatively correlated with milling outturn (r= -0.633, p<0.01). Cooking time was highly significant and negatively correlated with head rice recovery (r= -0.578, p<0.01). Alkali spreading value was highly significant and negatively correlated with cooking time as well as volume expansion ratio (r= -0.598, r= -688, p<0.01). Cooking time, elongation ratio and alkali spreading value were positively correlated with milling outturn. Volume expansion ratio was also positively correlated with hull content (Table-4.3.2a).

Pearson correlation coefficients for relationships had among various milling and cooking parameters of different medium grain rice cultivars. Cooking time as well as elongation ratio were significant and positively correlated with milling outturn (r=0.313, r=0.361, p<0.05). Alkali spreading value was significant and negatively correlated with cooking time (r= -0.318, p<0.05). Hull content was highly significant and negatively correlated with milling outturn (r= -0.760, p<0.01). Cooking time was highly significant and negatively correlated with head rice recovery (r= -0.396, p<0.01). Elongation ratio was highly significant and negatively correlated with hull content (r= -0.413, p<0.01). Head rice recovery was positively correlated with milling outturn. Elongation ratio was positively correlated with head rice recovery. Volume expansion ratio was positively correlated with milling outturn, head rice recovery and elongation ratio. Alkali spreading value was positively correlated with hull content and elongation ratio (Table-4.3.2b).

Pearson correlation coefficients for relationships had among various milling and cooking parameters of different short grain rice cultivars. Volume expansion ratio was highly significant and positively correlated with head rice recovery (r=0.530, p<0.01). Elongation ratio was significant and positively correlated with head rice recovery (r=0.459, p<0.05). Volume expansion ratio was significant and positively correlated with milling outturn (r=0.390, p<0.05). Volume expansion ratio was significant and negatively correlated with hull content (r= -0.421, p<0.05). Hull content was highly significant and negatively correlated with milling outturn (r= -0.496, p<0.01). Head rice recovery was positively correlated with milling outturn. Cooking time was positively correlated with milling outturn and hull content. Elongation ratio was positively correlated with milling outturn. Volume expansion ratio was positively correlated with elongation ratio. Alkali spreading value was positively correlated with milling outturn, hull content, cooking time and elongation ratio (Table-4.3.2c).

4.3.11 Cluster analysis of milling and cooking properties

Milling properties (milling outturn, head rice recovery and hull content) of milling quality based clustering provided four clusters at level 5 for long grain local rice cultivars(Figure-4.3.4). Cluster-1 consisted of 19 cultivars; These cultivars comprising cluster-1 was characterized by higher head rice recoveryhaving the range of (88-95)%. Cluster-2 consisted of 5 cultivars; Jingasail-1, Sadajira Tapl-321, Cylindrical Tapi-629, TK deep straw Tapl-773 and Kalabinni-1comprising cluster-2 was characterized by lower milling outturn having the range of (66-69)%.Cluster-3 consisted of 3 cultivars; Kharmao, Jol and Karailadhancomprising cluster-3was characterized by lowest milling outturn, lower head rice recovery and highest hull content having the ranges of (63-67)%,(75-84)% and (25-27)% respectively.Cluster-4 consisted of 5 cultivars; Molladigha, Dudhkalam, Boradudhkalam, Depa and Neda comprising cluster-4was characterized by lowest head rice recovery having the range of (41-71)%.

Cooking properties (cooking time, alkali spreading value, gelatinization temperature, elongation ratio and volume expansion ratio) of cooking quality based clustering provided six clusters at level 5 for long grain local rice cultivars (Figure-4.3.5). Cluster-1 consisted of 2 cultivars; Molladigha and jol comprising cluster-1 was characterized by cooking time of 23 minutes, alkali spreading value of 3.5, volume expansion ratio of 4, elongation ratio having the range of (1.9-2.0) as well as intermediate gelatinization temperature. Cluster-2 consisted of 8 cultivars; Khorma, Kanaibansi, Kharmao, Dudhkalam, Bhorochalam, Depa, Dudsar Tapal-146 and Shithabhog comprising cluster-2 was characterized by cooking time having the range of (17-19) minutes, elongation ratio having the range of (1.6-1.9) as well as volume expansion ratio having the range of (3.4-3.9). Cluster-3 consisted of 5 cultivars; Joalbagh, Neda, Jingasail-1, Boradudhkalam and Harilaxmi comprising cluster-3 was characterized by volume expansion ratio having the range of (3.4-3.9), cooking time having the range of (19-21) minutes, alkali spreading value having the range of (4.6-5.0) as well as intermediate gelatinization temperature. Cluster-4 consisted of 7 cultivars; Lathamona, Binni-1, Kalabinni-1, Cylindrical Tapi-629, Athabinni, Gohatibinni and Hatisail comprising cluster-4 was characterized by alkali spreading value having the range of (6.0-7.0) as well as low gelatinization temperature. Cluster-5 consisted of 9 cultivars; Pakhisail, Redpiebald-219, Kalamanik, Binni-2, T.R.Aman, TK deep straw Tapl-773, Patnai-231, Shata and Sadajira Tapl-321 comprising cluster-5 was characterized by cooking time having the range of(16-18) minutes, volume expansion ratio having the range of (3.4-3.7), elongation ratio having the range of (1.6-2.0) as well as alkali spreading value having the range of (4.3-5.7). Cluster-6 consisted of 1 cultivar; Karialadhan comprising cluster-6 was characterized by cooking time of 15 minutes and intermediate gelatinization temperature. All cultivars had the range of cooking time of (15-16) minutes with low gelatinization temperature except Karialadhan.

Table-4.3.1a: Mean performance of milling and cooking properties for 36 long grain rice cultivars

Sl. No.	Cultivars	Milling outturn (%)	Head rice recovery (%)	Hull content (%)	Alkali spreading value	Gelatinizationtem perature	Aroma	Cooking time (min)	Elongation ratio	Volume expansion ratio
1	Athabinni	68±0.61	95±0.26	23±0.96	6.6±0.24	Low	–	16±0.65	1.6±0.15	3.1±0.09
2	Bhorochalam	69±1.04	92±0.38	23±0.52	5.0±0.35	Intermediate	–	19±1.37	1.6±0.20	3.6±0.12
3	Binni -1	70±0.71	92±0.89	24±0.61	6.1±0.16	Low	–	16±0.44	1.7±0.13	3.3±0.21
4	Binni -2	70±0.34	91±0.61	23±0.64	5.3±0.37	Intermediate	–	18±0.83	1.6±0.12	3.6±0.18
5	Boradudhkalam	69±0.77	64±0.58	21±0.83	5.0±0.26	Intermediate	–	21±0.90	1.9±0.00	3.7±0.14
6	Cylindrical Tapi-629	66±0.83	96±0.59	25±0.45	7.0±0.06	Low	–	16±0.72	1.8±0.06	3.4±0.06
7	Depa	67±0.58	58±1.39	22±0.95	5.1±0.11	Intermediate	–	19±0.66	1.9±0.12	3.6±0.20
8	Dudhkalam	67±1.00	51±1.48	22±1.46	4.9±0.19	Intermediate	–	19±0.63	1.7±0.12	3.4±0.27
9	Dudsar Tapal-146	70±0.45	89±0.58	21±0.55	5.1±0.26	Intermediate	–	19±0.57	1.8±0.17	3.7±0.05
10	Gohatibinni	69±0.93	92±0.45	23±0.32	6.7±0.16	Low	–	15±0.70	1.5±0.10	3.1±0.17
11	Harilaxmi	71±0.77	93±0.55	22±1.06	4.7±0.20	Intermediate	–	20±0.51	1.9±0.06	3.7±0.06
12	Hatisail	67±1.84	91±1.53	25±0.69	6.0±0.74	Low	+	18±0.79	1.8±0.15	3.6±0.05
13	Jingasail-1	66±0.96	96±0.39	26±0.28	4.6±0.44	Intermediate	+	19±1.73	1.5±0.10	3.4±0.12
14	Joalbagh	69±0.97	90±0.52	23±0.74	4.9±0.23	Intermediate	–	19±1.00	1.9±0.15	3.9±0.19
15	Jol	66±0.58	75±1.58	25±0.51	3.5±0.35	Intermediate	–	23±0.52	1.9±0.17	3.9±0.25
16	Kalabinni-1	67±0.97	87±1.48	23±1.05	6.5±0.25	Low	–	16±0.81	1.8±0.15	3.1±0.08
17	Kalimanik	67±0.50	92±0.79	25±0.46	5.6±0.10	Low	–	18±0.58	1.6±0.10	3.7±0.21
18	Kanaibansi	65±0.61	90±0.74	26±0.47	3.2±0.14	Intermediate	–	17±0.84	1.6±0.06	3.7±0.33
19	Karaildhan	67±1.19	80±1.22	25±0.57	4.5±0.24	Intermediate	–	15±1.38	1.7±0.10	3.7±0.08
20	Kharmao	63±0.80	84±0.77	27±0.38	3.7±0.22	Intermediate	–	18±0.60	1.7±0.06	3.9±0.08
21	Khorma	67±0.67	90±0.62	25±1.05	4.0±0.18	Intermediate	–	17±0.32	1.6±0.15	3.7±0.13
22	Lathamona	66±0.64	93±0.45	24±0.62	6.3±0.26	Low	–	16±0.96	1.8±0.06	3.7±0.13
23	Molldigha	70±1.96	41±1.39	22±0.87	3.5±0.14	Intermediate	–	23±0.42	2.0±0.15	4.0±0.16
24	Neda	69±0.28	71±1.80	21±1.01	4.6±0.08	Intermediate	–	19±0.54	1.7±0.06	3.9±0.32
25	Pakhisail	68±0.44	91±0.55	24±1.03	4.3±0.18	Intermediate	–	18±0.58	1.7±0.12	3.7±0.10
26	Patnai-231	69±1.16	88±1.01	24±0.28	5.5±0.30	Low	–	17±0.58	1.8±0.06	3.4±0.21
27	Redpiebald-219	69±1.35	94±0.34	22±1.34	5.5±0.32	Low	–	18±0.74	1.7±0.06	3.6±0.15
28	Sadajira Tapl-321	68±0.81	86±1.36	23±0.38	5.5±0.34	Low	–	16±1.00	1.8±0.12	3.6±0.09
29	Shata	69±0.95	92±1.83	22±1.53	5.3±0.33	Intermediate	–	17±0.66	1.6±0.10	3.6±0.12
30	Shithabhog	69±0.51	88±0.58	23±0.51	5.3±0.23	Intermediate	–	19±0.90	1.8±0.15	3.6±0.11
31	T.R.Aman	68±0.58	91±0.57	23±0.22	5.7±0.21	Low	–	17±0.73	2.0±0.17	3.6±0.12
32	TK deep straw Tapl-773	69±1.29	86±0.77	22±0.58	5.7±0.18	Low	–	17±0.60	1.7±0.10	3.7±0.22
33	BR23	69±0.58	91±1.10	22±1.26	6.5±0.27	Low	–	17±1.11	1.6±0.06	3.7±0.21
34	BRRI dhan30	70±1.01	96±0.40	22±0.40	5.8±0.07	Low	–	18±0.97	1.8±0.12	4.0±0.10
35	BRRI dhan39	71±0.97	96±0.39	21±1.73	4.8±0.16	Intermediate	–	19±0.56	1.8±0.06	4.0±0.13
36	BRRI dhan41	70±0.38	94±0.51	22±1.00	6.0±0.29	Low	–	17±0.23	1.9±0.12	3.9±0.07
Range		**63-71**	**41-96**	**21-27**	**3.2-7.0**			**15-23**	**1.5-2.0**	**3.1-4.0**
Mean±SD		**68±1.76**	**86±13.07**	**23±1.57**	**5.2±0.95**			**18±1.87**	**1.7±0.13**	**3.6±0.24**
CV%		**3**	**15**	**7**	**18**			**10**	**8**	**7**
SE (Standard error)		**0.4733**	**0.4531**	**0.4035**	**0.9087-01**			**0.4156**	**0.6721-01**	**0.4815**
LSD (0.05)		**1.3348**	**1.2779**	**1.13806**	**0.2562**			**1.172**	**0.1895**	**0.1358**

Table-4.3.1b: Mean performance of milling and cooking properties for 62 medium grain rice cultivars

Sl. No.	Cultivars	Milling outturn (%)	Head rice recovery (%)	Hull content (%)	Alkali spreading value	Gelatinization temperature	Aroma	Cooking time (min)	Elongation ratio	Volume expansion ratio
1	Bariksail	70±0.40	95±0.45	23±0.49	5.7±0.19	Low	–	17±1.64	1.9±0.10	4.0±0.23
2	Bolonga	74±0.53	95±0.85	20±1.39	4.6±0.19	Intermediate	–	19±0.63	1.7±0.12	4.0±0.17
3	Boylam	66±1.00	44±1.44	25±0.34	3.8±0.20	Intermediate	–	22±0.84	1.7±0.10	3.6±0.14
4	Chamara	67±0.83	85±1.74	26±0.21	5.2±0.17	Intermediate	–	20±0.81	1.9±0.10	3.7±0.10
5	Changai	71±0.32	86±1.00	21±0.58	4.7±0.21	Intermediate	–	20±0.70	2.0±0.15	3.7±0.17
6	Dad khani	68±0.58	92±1.01	23±0.62	5.0±0.16	Intermediate	–	17±1.52	1.8±0.15	4.0±0.18
7	Dholagachha	70±0.58	85±0.55	22±0.81	4.0±0.29	Intermediate	–	22±0.75	1.9±0.10	3.6±0.13
8	Ganjia	69±0.58	92±0.33	22±0.93	5.9±0.23	Low	–	14±0.89	2.2±0.10	3.6±0.14
9	Gobcha	69±1.54	89±0.90	23±1.53	4.5±0.34	Intermediate	–	20±0.33	1.9±0.12	3.3±0.22
10	Gojalgoria	69±0.70	53±1.46	23±1.28	4.9±0.17	Intermediate	–	18±0.33	1.9±0.15	3.9±0.39
11	Hashfol	68±0.33	84±1.31	23±0.56	4.8±0.33	Intermediate	–	20±1.79	2.1±0.00	4.3±0.11
12	Hathazi	73±1.00	96±0.65	20±0.65	5.0±0.33	Intermediate	–	21±1.08	1.9±0.15	3.6±0.18
13	Hijli	70±0.83	92±0.76	24±0.29	5.8±0.11	Low	–	18±0.92	1.7±0.06	3.7±0.19
14	Jhingasail-2	68±0.64	70±0.58	22±1.29	4.0±0.13	Intermediate	+	21±0.74	2.2±0.06	4.0±0.16
15	Jhoshua	64±1.58	89±1.51	26±0.36	5.3±0.17	Intermediate	–	16±1.03	1.6±0.06	3.6±0.12
16	Joyna	69±0.38	85±1.52	23±1.33	6.8±0.08	Low	–	20±0.93	1.7±0.06	3.9±0.20
17	Kajalsail	70±1.02	95±0.51	21±1.39	4.8±0.15	Intermediate	–	20±0.93	1.8±0.12	3.4±0.04
18	Kalabinni-2	67±0.54	92±0.42	24±0.57	4.8±0.07	Intermediate	–	18±1.00	1.8±0.15	3.7±0.06
19	Kalisayta	69±1.35	65±0.80	24±0.50	4.0±0.30	Intermediate	–	23±0.39	1.7±0.10	3.7±0.06
20	Kanaklata	70±0.84	97±0.65	23±0.58	4.9±0.12	Intermediate	–	15±0.80	2.0±0.10	3.9±0.11
21	Katari bhog-232	65±0.69	93±0.75	24±0.58	5.1±0.20	Intermediate	–	14±0.74	1.5±0.21	4.0±0.18
22	Kataribhog-1	66±1.17	90±0.51	25±0.44	5.0±0.16	Intermediate	+	14±0.42	1.8±0.10	3.9±0.07
23	Kataribhog-2	68±0.57	96±0.46	20±0.45	5.7±0.24	Low	+	14±1.67	2.0±0.06	3.6±0.13
24	Kumragoir	69±0.41	94±0.39	21±1.12	4.7±0.12	Intermediate	–	22±1.00	2.0±0.12	4.0±0.28
25	Lalbinni	69±0.89	83±0.57	23±0.94	4.5±0.18	Intermediate	–	17±0.52	2.0±0.06	3.6±0.35
26	Lalmota	72±0.44	86±1.00	21±0.55	6.5±0.14	Low	–	22±0.44	2.0±0.12	3.9±0.27
27	Lalsoru	66±0.64	92±0.48	23±0.55	5.4±0.32	Intermediate	+	13±0.57	1.5±0.10	3.7±0.13
28	Ledabinni	67±0.56	75±1.86	24±0.53	6.8±0.20	Low	–	16±0.51	1.5±0.13	3.4±0.11
29	Lohasail	72±0.86	90±0.51	22±0.73	5.6±0.43	Low	–	18±0.58	2.1±0.12	3.9±0.26
30	Magoibalam	67±1.14	66±1.59	26±0.38	3.8±0.26	Intermediate	–	21±0.84	1.5±0.12	3.4±0.20
31	Maloti	69±0.49	91±0.65	23±0.64	5.7±0.27	Low	+	15±0.00	2.2±0.06	3.6±0.08
32	Malsira	68±0.49	85±1.54	22±0.73	4.8±0.22	Intermediate	–	18±0.61	1.7±0.06	3.6±0.07
33	Motichak	68±1.00	26±1.35	24±0.42	4.0±0.25	Intermediate	–	22±1.00	1.7±0.10	3.4±0.07
34	Najirsail	70±0.52	95±0.85	23±0.38	5.8±0.11	Low	–	16±0.77	2.1±0.31	4.0±0.13

Sl. No.	Cultivars	Milling outturn (%)	Head rice recovery (%)	Hull content (%)	Alkali spreading value	Gelatinization temperature	Aroma	Cooking time (min)	Elongation ratio	Volume expansion ratio
35	Nakchi	66±0.61	96±0.78	23±0.83	6.4±0.27	Low	–	19±0.84	2.0±0.06	3.7±0.12
36	Nizersail	70±0.70	95±0.65	23±0.50	5.1±0.10	Intermediate	–	16±1.09	2.1±0.06	3.7±0.11
37	Nunia	67±1.18	89±0.59	24±0.35	5.3±0.10	Intermediate	+	16±0.60	1.9±0.10	3.9±0.37
38	Paharisail	66±0.96	96±0.58	25±0.64	5.2±0.19	Intermediate	–	18±0.58	1.8±0.26	3.7±0.06
39	Pakibiroin	70±0.33	95±0.78	22±1.35	4.0±0.17	Intermediate	–	22±0.88	1.7±0.06	3.4±0.16
40	Poushmoricha	69±1.70	79±1.48	22±1.44	4.8±0.13	Intermediate	–	18±1.24	2.0±0.12	3.6±0.17
41	Putidepa	64±1.34	88±1.68	26±0.47	5.2±0.35	Intermediate	–	17±0.38	2.0±0.17	3.4±0.10
42	Rajamora	67±0.51	94±0.41	24±0.38	5.1±0.28	Intermediate	–	19±0.29	1.8±0.08	3.7±0.07
43	Rangabinni	67±1.12	90±0.70	25±1.18	7.0±0.06	Low	–	16±0.70	1.6±0.15	3.1±0.06
44	Sadamota	69±0.57	95±0.51	22±0.28	6.3±0.22	Low	–	19±0.47	2.2±0.06	3.4±0.07
45	Shamrosh	70±1.44	67±1.39	22±1.06	5.2±0.26	Intermediate	–	18±0.60	2.1±0.00	4.0±0.12
46	Somondori	69±0.58	92±0.50	23±0.74	5.5±0.18	Low	–	16±0.58	2.1±0.12	3.6±0.10
47	Tilkapur	69±0.51	79±0.58	23±0.58	4.9±0.44	Intermediate	–	17±0.68	1.9±0.15	3.7±0.25
48	Tilokkajal	70±0.51	91±0.50	21±1.53	5.3±0.26	Intermediate	–	20±0.97	2.0±0.12	3.4±0.08
49	BR4	70±1.39	95±0.53	22±1.00	5.7±0.18	Low	–	17±1.01	1.9±0.10	4.0±0.17
50	BR10	72±0.94	95±0.70	22±0.89	5.1±0.21	Intermediate	–	19±0.46	1.7±0.00	4.0±0.10
51	BR11	70±0.71	91±0.53	21±0.97	5.6±0.23	Low	–	17±0.42	1.7±0.10	3.7±0.05
52	BR22	70±0.58	97±0.59	22±0.70	6.3±0.19	Low	–	16±0.95	1.8±0.23	4.0±0.17
53	BR25	70±2.00	98±0.72	22±0.77	5.4±0.28	Intermediate	–	16±1.16	1.6±0.15	3.7±0.10
54	BRRI dhan31	73±0.38	96±1.17	19±0.83	6.0±0.40	Low	–	21±0.74	1.6±0.06	3.9±0.07
55	BRRI dhan32	70±0.35	97±1.85	22±0.95	6.1±0.17	Low	–	17±1.00	2.0±0.06	3.9±0.30
56	BRRI dhan33	71±0.45	88±0.51	21±0.49	4.8±0.11	Intermediate	–	21±1.33	2.1±0.12	4.0±0.16
57	BRRI dhan37	71±1.35	97±0.62	21±0.55	5.5±0.17	Low	–	14±0.52	1.9±0.00	3.9±0.11
58	BRRI dhan38	71±0.58	95±0.43	21±1.06	5.5±0.14	Low	–	16±1.00	1.9±0.10	3.6±0.06
59	BRRI dhan40	72±1.54	93±0.69	20±1.07	6.0±0.24	Low	–	22±1.24	1.9±0.12	4.0±0.15
60	BRRI dhan44	70±0.58	88±0.85	21±1.33	5.8±0.16	Low	–	22±0.46	1.9±0.20	3.6±0.17
61	BRRI dhan46	59±2.37	88±0.90	20±0.57	5.2±0.14	Intermediate	–	19±0.45	1.8±0.10	3.7±0.08
62	BRRI dhan49	71±0.69	98±0.61	23±0.58	4.0±0.22	Intermediate	–	17±0.74	1.8±0.06	4.0±0.18
Range		**59-74**	**26-98**	**19-26**	**3.8-7.0**			**13-23**	**1.5-2.2**	**3.1-4.3**
Mean±SD		**69±2.47**	**87±13.28**	**23±1.64**	**5.2±0.76**			**18±2.57**	**1.9±0.19**	**3.7±0.23**
CV%		**4**	**15**	**7**	**14**			**14**	**10**	**6**
SE (Standard error)		**0.5214**	**0.3980**	**0.3998**	**0.7692-01**			**0.2773**	**0.6994-01**	**0.4829-01**
LSD (0.05)		**1.4596**	**1.114**	**1.119**	**0.2153**			**0.7764**	**0.1958**	**0.1351**

Table-4.3.1c: Mean performance of milling and cooking properties for 31 short grain rice cultivars

Sl. No.	Cultivars	Milling outturn (%)	Head rice recovery (%)	Hull content (%)	Alkali spreading value	Gelatinizationtemperature	Aroma	Cooking time (min)	Elongation ratio	Volume expansion ratio
1	Baoijhaki	69±1.10	93±0.77	22±1.00	4.8±0.13	Intermediate	+	16±1.16	2.2±0.23	3.9±0.32
2	Betudhan	66±1.55	88±0.78	25±0.39	4.9±0.22	Intermediate	−	18±0.79	1.9±0.06	3.6±0.10
3	Binniphul	67±1.14	97±0.82	25±1.00	5.8±0.08	Low	−	16±1.50	2.0±0.30	3.4±0.12
4	Chinisagor	59±2.52	94±0.80	23±0.47	4.0±0.11	Intermediate	+	14±1.00	2.0±0.21	3.4±0.23
5	Chinigura	65±0.91	98±0.28	22±0.50	5.8±0.16	Low	+	14±0.58	2.1±0.29	3.9±0.32
6	Chunikanai	70±0.62	97±0.67	20±0.58	4.5±0.16	Intermediate	−	14±0.92	2.3±0.06	4.0±0.28
7	Dudsail	70±1.84	98±0.46	22±0.83	4.9±0.41.	Intermediate	−	16±0.88	2.1±0.30	3.7±0.06
8	Gurdoi	71±0.51	97±1.11	23±0.58	5.5±0.21	Low	−	18±1.47	2.0±0.00	4.0±0.15
9	Jabsira	69±1.29	94±0.57	22±0.96	4.3±0.16	Intermediate	+	14±0.90	1.9±0.21	3.9±0.18
10	Jirakatari-1	69±1.53	93±0.38	23±0.34	4.1±0.23	Intermediate	+	14±0.78	1.8±0.00	3.7±0.07
11	Jirakatari-2	68±0.61	97±0.89	23±0.27	5.4±0.24	Intermediate	+	13±0.28	1.9±0.10	3.9±0.11
12	Kalasaru	64±0.44	75±0.82	24±0.90	4.2±0.24	Intermediate	+	14±0.41	1.9±0.17	3.7±0.19
13	Kalijira	69±0.48	97±1.39	22±0.55	5.7±0.21	Low	+	14±0.93	2.1±0.06	3.9±0.06
14	Khasha	70±1.78	95±1.07	22±0.51	3.9±0.27	Intermediate	+	13±0.50	2.2±0.17	3.7±0.10
15	Lalsaru	66±1.47	97±0.35	22±1.01	4.8±0.18	Intermediate	−	14±1.03	2.3±0.10	3.9±0.22
16	Laxmikajol	67±0.17	83±1.40	23±0.44	4.0±0.35	Intermediate	−	14±0.57	1.8±0.26	3.6±0.09
17	Malagrosa	70±0.38	95±0.53	22±1.01	4.0±0.19	Intermediate	−	14±0.89	2.1±0.06	3.7±0.11
18	Michisail	69±0.80	92±0.65	22±0.51	4.8±0.18	Intermediate	−	14±0.45	1.9±0.00	3.9±0.22
19	Minki	69±0.65	92±0.55	23±0.65	6.2±0.16	Low	−	21±0.79	2.1±0.15	3.4±0.12
20	Murchmut	65±1.32	84±0.73	25±0.39	6.4±0.28	Low	−	17±0.62	2.1±0.10	3.4±0.13
21	Nariabochi	68±0.84	76±0.92	22±0.58	5.6±0.12	Low	−	18±0.69	1.8±0.10	3.4±0.06
22	Nurior	72±0.69	97±0.45	22±0.50	5.3±0.27	Intermediate	+	23±0.79	1.8±0.10	3.7±0.08
23	Pajam	70±0.58	97±0.80	23±0.64	5.1±0.27	Intermediate	−	18±0.70	2.0±0.26	4.0±0.13
24	Rahikhama	70±0.49	88±0.70	22±1.23	5.1±0.43	Intermediate	−	22±0.58	2.0±0.15	3.6±0.14
25	Sorukamina	70±0.58	97±0.57	21±1.01	4.3±0.30	Intermediate	+	14±0.30	2.1±0.06	3.9±0.13
26	Surjyamukhisangla	72±0.39	97±0.90	21±0.75	4.8±0.17	Intermediate	−	14±0.84	2.3±0.06	3.9±0.09
27	Topaboro	70±1.38	94±0.95	23±0.70	4.4±0.26	Intermediate	+	21±0.91	1.9±0.06	3.7±0.10
28	Tulsimala	68±1.17	89±0.93	25±0.57	6.1±0.14	Low	+	18±0.71	2.0±0.10	3.6±0.09
29	Uknimadhu	65±1.38	96±0.44	26±0.50	3.7±0.25	Intermediate	+	14±1.00	2.2±0.15	3.9±0.17
30	BR5	68±0.50	96±1.67	25±0.39	5.3±0.15	Intermediate	+	13±0.95	2.1±0.26	4.0±0.13
31	BRRI dhan34	68±1.11	96±0.73	21±0.51	4.2±0.19	Intermediate	+	13±0.61	2.2±0.25	4.0±0.16
Range		**59-72**	**75-98**	**20-26**	**3.7-6.4**			**13-23**	**1.8-2.3**	**3.4-4.0**
Mean±SD		**68±2.66**	**93±6.08**	**23±1.43**	**4.9±0.75**			**16±2.87**	**2.0±0.15**	**3.8±0.20**
CV%		**4**	**7**	**6**	**15**			**18**	**7**	**5**
SE (Standard error)		**0.6345**	**0.3214**	**0.3707**	**0.9980-01**			**0.2276**	**0.9729-01**	**0.3990-01**
LSD (0.05)		**1.794**	**0.9093**	**1.0486**	**0.2823**			**0.6440**	**0.2751**	**0.1128**

Table-4.3.2a: The Pearson correlation coefficient for milling and cooking properties on the basis of different long grain rice cultivars

Correlations

Parameters	**Milling outturn (%)**	**Head ricerecovery (%)**	**Hull content (%)**	**Cooking time (min)**	**Elongation ratio**	**Volume expansion ratio**
Milling outturn (%)	1					
Head rice recovery (%)	-.032	1				
Hull content (%)	-.633**	.409*	1			
Cooking time (min)	.167	-.578**	-.184	1		
Elongation ratio	.149	-.436*	-.238	.459**	1	
Volume expansion ratio	-.042	-.331	.027	.591**	.389*	1
Alkali spreading value	.172	.445*	-.213	-.598**	-.110	-.688**

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table-4.3.2b: The Pearson correlation coefficient for milling and cooking properties on the basis of different medium grain rice cultivars

Correlations

Parameters	Milling outturn (%)	Head ricerecovery (%)	Hull content (%)	Cooking time (min)	Elongation ratio	Volume expansion ratio
Milling outturn (%)	1					
Head rice recovery (%)	.137	1				
Hull content (%)	-.760**	-.257	1			
Cooking time (min)	.313*	-.396**	-.167	1		
Elongation ratio	.361*	.195	-.413**	-.020	1	
Volume expansion ratio	.058	.049	-.068	-.128	.219	1
Alkali spreading value	-.155	-.002	.112	-.318*	.029	-.151

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table-4.3.2c: The Pearson correlation coefficient for milling and cooking properties on the basis of different short grain rice cultivars

Correlations

Parameters	**Milling outturn (%)**	**Head rice recovery (%)**	**Hull content (%)**	**Cooking time (min)**	**Elongation ratio**	**Volume expansion ratio**
Milling outturn (%)	1					
Head rice recovery (%)	.326	1				
Hull content (%)	-.496**	-.296	1			
Cooking time (min)	.308	-.142	.144	1		
Elongation ratio	.056	.459*	-.254	-.309	1	
Volume expansion ratio	.390*	.530**	-.421*	-.360	.340	1
Alkali spreading value	.019	-.002	.096	.288	.044	-.210

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

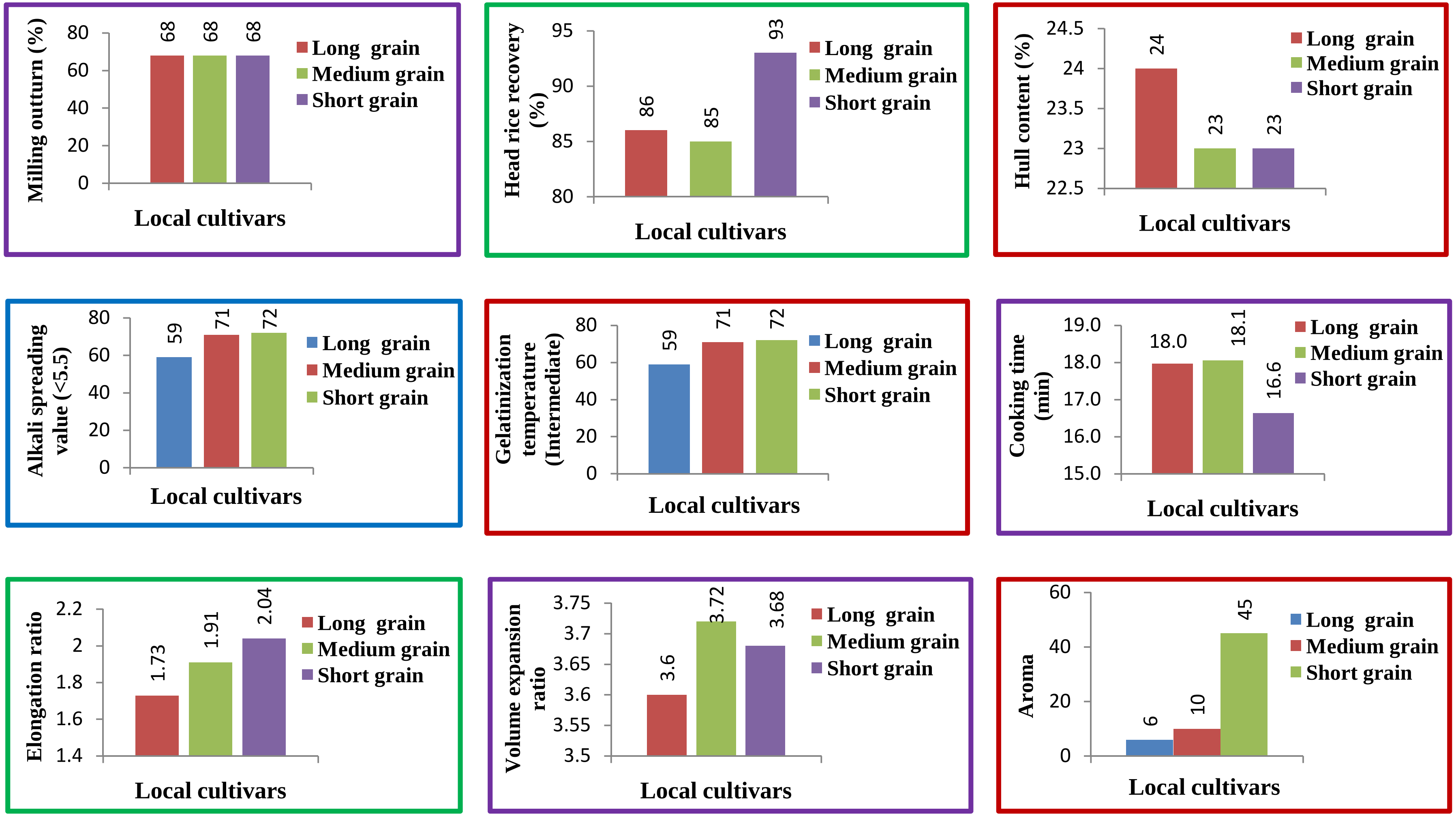

Figure-4.3.1: Comparison of milling and cooking quality for long, medium and short grain local rice cultivars

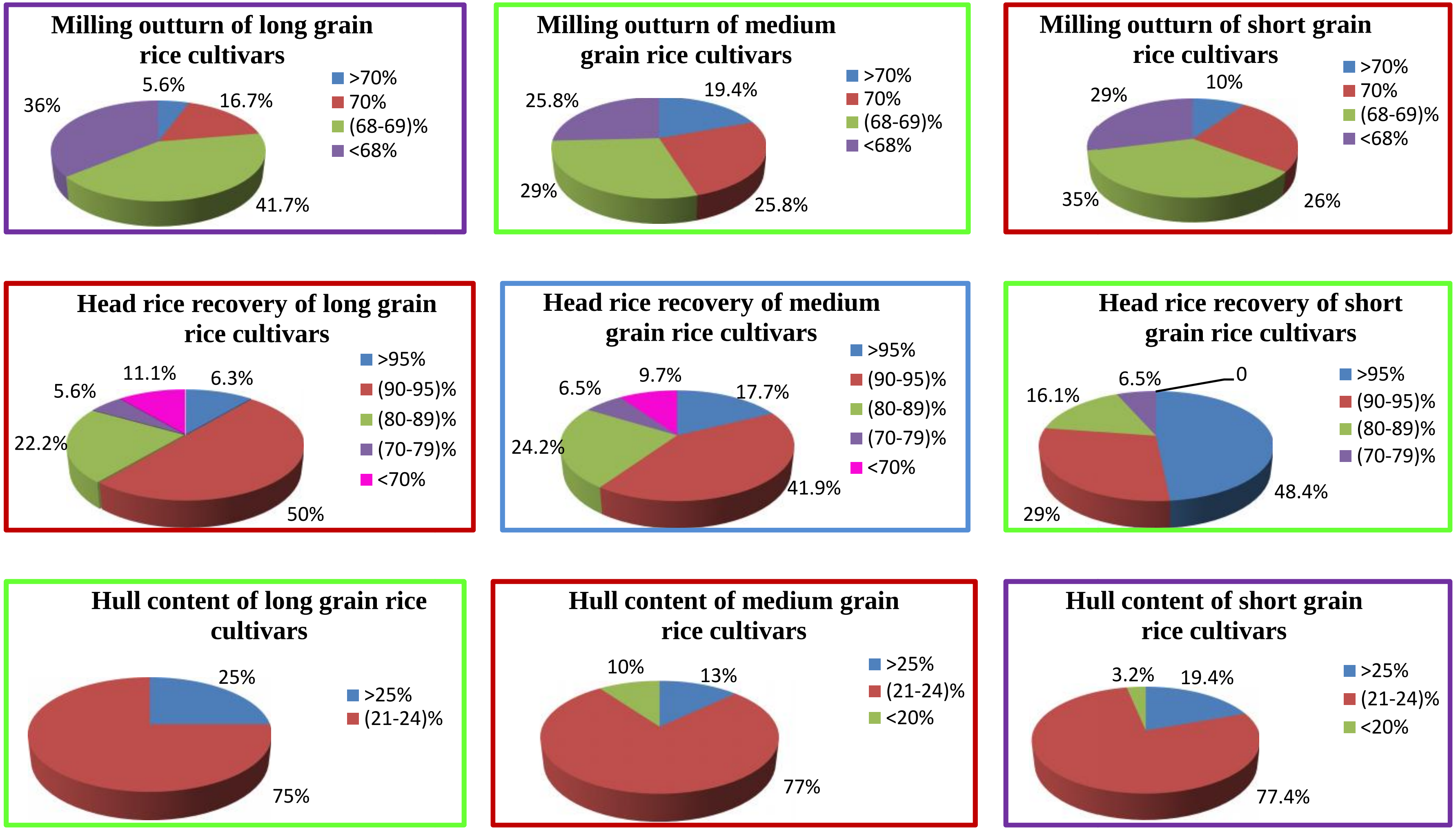

Figure-4.3.2a : Frequency distribution ofmilling quality for long, medium and short grain rice cultivars

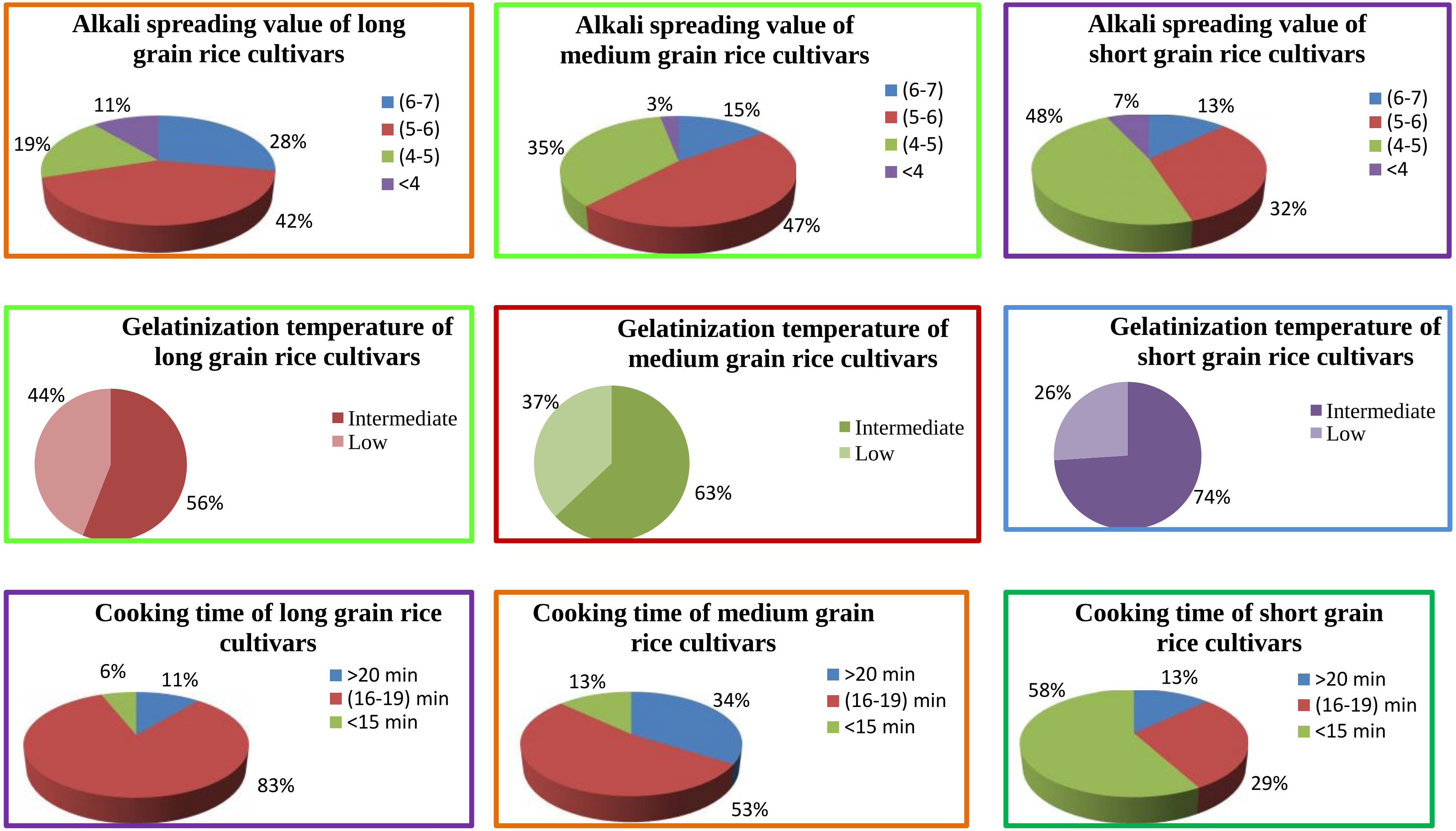

Figure-4.3.2b : Frequency distribution ofcooking quality for long, medium and short grain rice cultivars

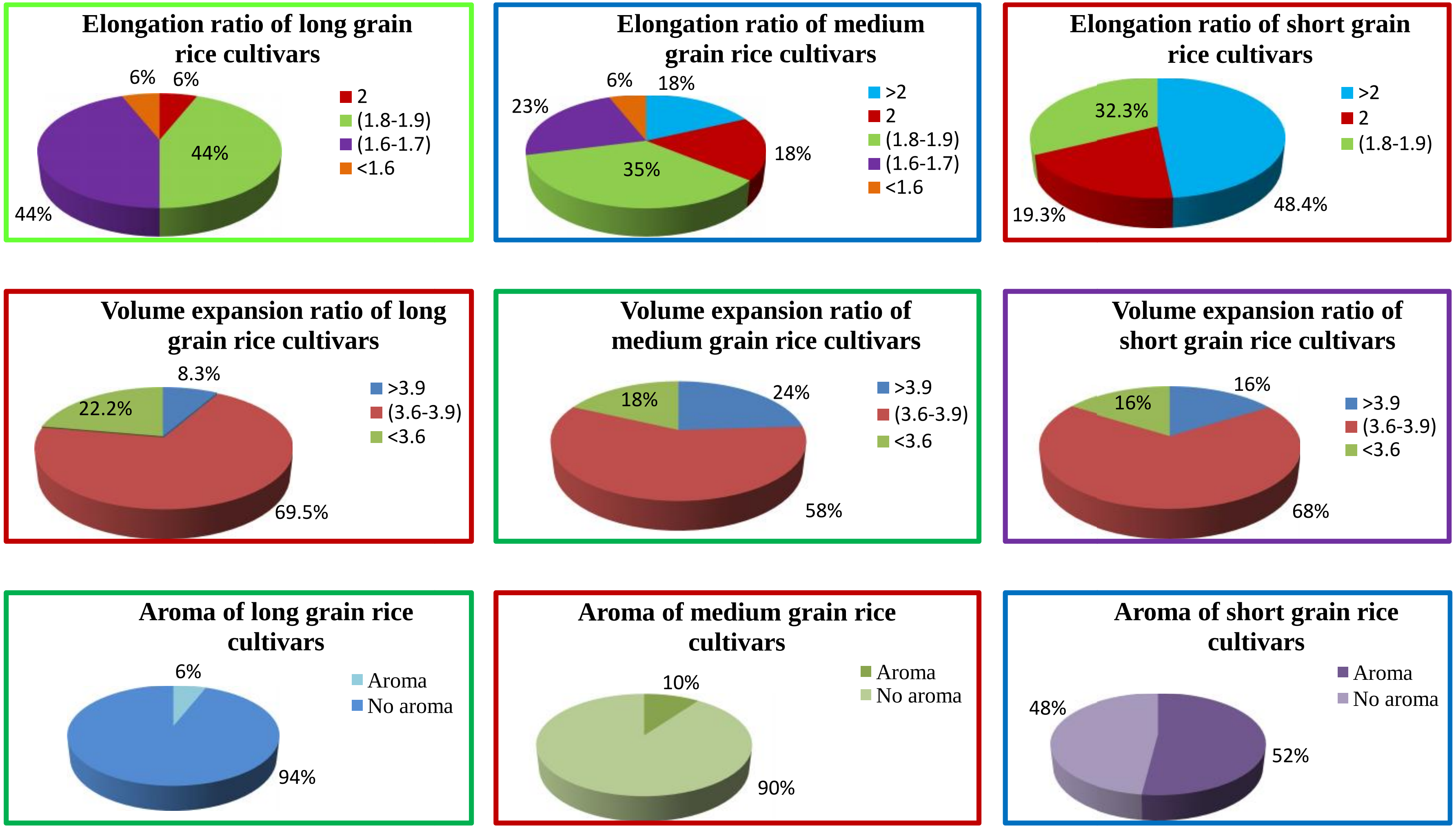

Figure-4.3.2c : Frequency distribution ofcooking quality for long, medium and short grain rice cultivars (contd.)

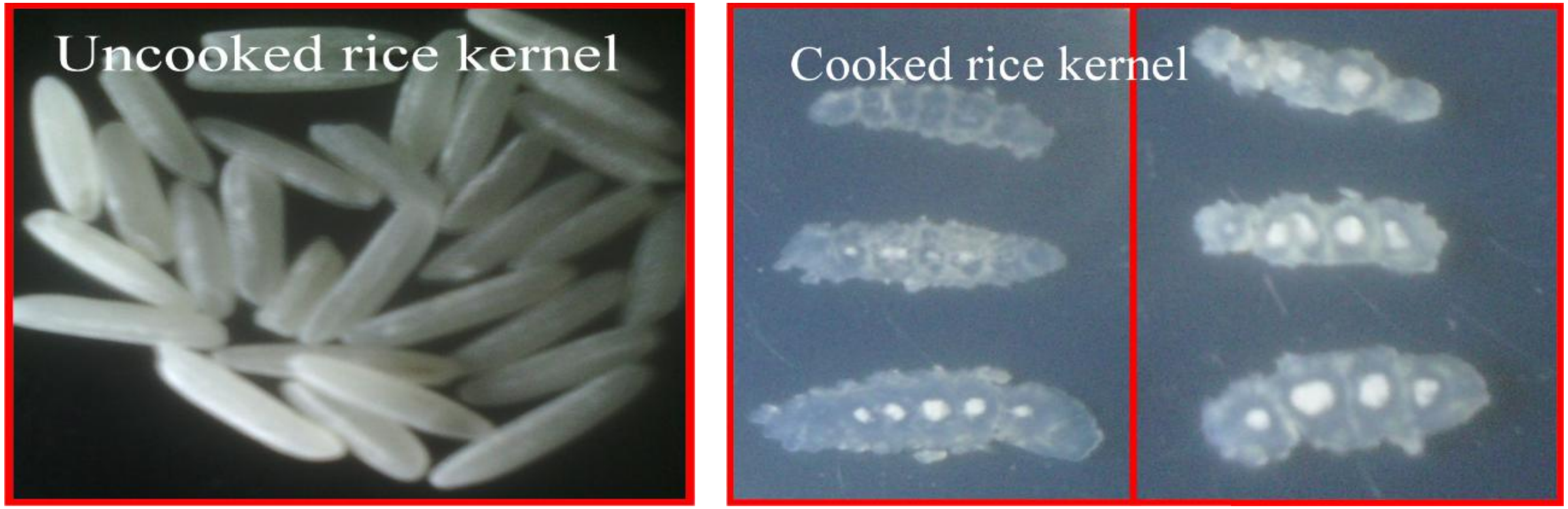

Figure-4.3.3: Appearance of uncooked and cooked rice kernel

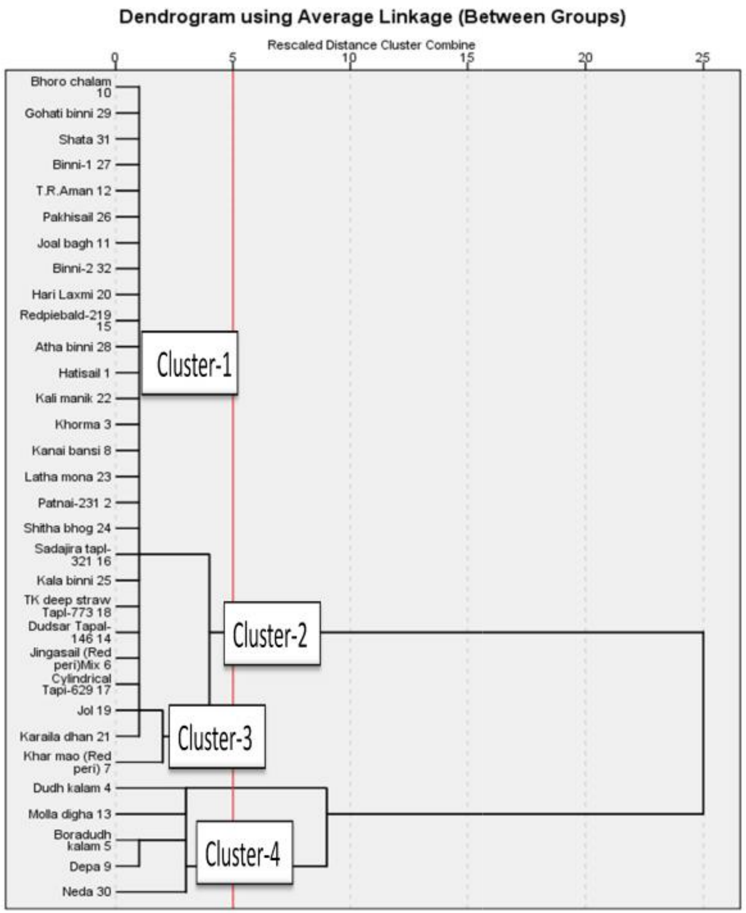

Figure-4.3.4: Dendrogram of long grain local rice cultivars based on milling quality

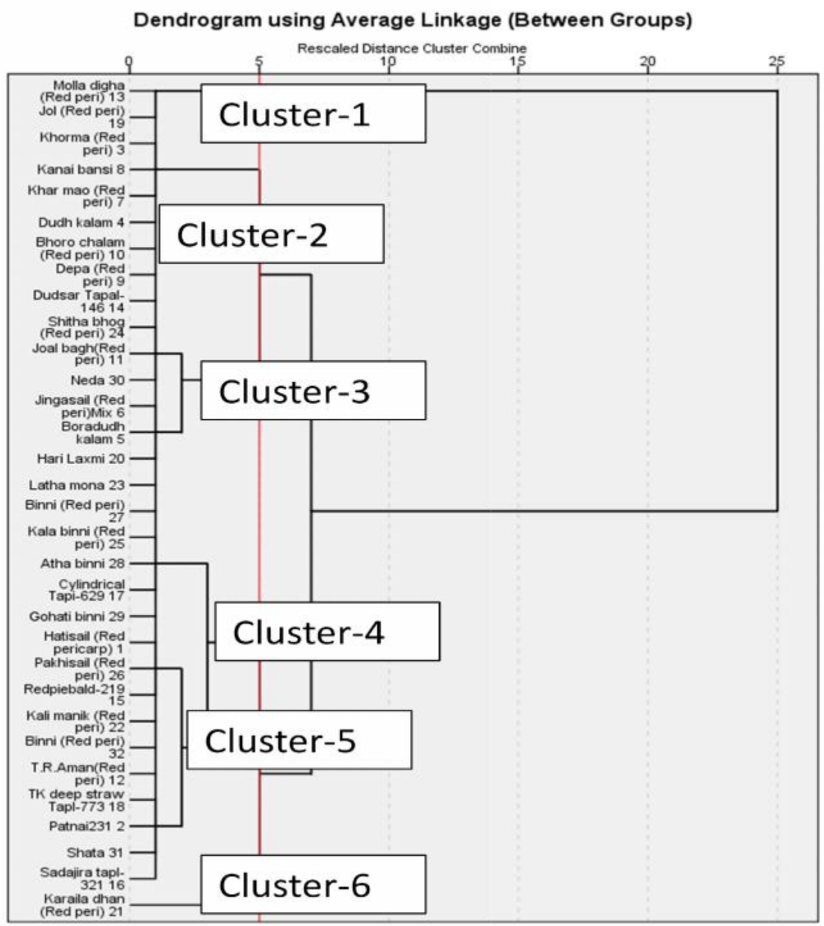

Figure-4.3.5: Dendrogram of long grain local rice cultivars based on cooking quality

4.4: Evaluation of mineral elements for long, medium and short grain rice cultivars

4.4 Mineral elements

In total, 129 rice cultivars including109 local rice cultivars and 20 HYVs of rice have been evaluated for mineral elements such as phosphorous (P), calcium (Ca), magnesium (Mg), nitrogen (N), potassium (K), sodium (Na), iron (Fe) and zinc (Zn).

4.4.1 Phosphorous content

The phosphorous content of all tested rice cultivars varied from 0.17% to 0.43%. Cultivars of Joalbagh had the highest phosphorous content (0.43%), whereas cultivars of Jhingasail-2 and Joyna had the lowest phosphorous content (0.20%). These local cultivars had higher phosphorous content than some HYVs such as BRRI dhan30, BRRI dhan31, BRRI dhan33, BRRI dhan40, BRRI dhan41 and BRRI dhan44 having the range of (0.17-0.19)%phosphorous content (Table-4.4.1a and Table-4.4.1b).

Phosphorous content of 36 long grain rice cultivars varied from 0.19% to 0.43% with the mean value of 0.33±0.051%. Among the long grain local rice cultivars, Joalbagh had the highest phosphorous content (0.43%) but Kalimanik had the lowest phosphorous content (0.29%). While, phosphorous content of HYVs varied from 0.19% to 0.28% (Table-4.4.1a). Phosphorous content of 62 medium grain rice cultivars varied from 0.17% to 0.41% with the mean value of 0.30±0.066%. Among the medium grain local rice cultivars, Magoibalam had the highest phosphorous content (0.41%) but Jhingasail-2 and Joyna had the lowest phosphorous content (0.20%). While, phosphorous content of HYVs varied from 0.17% to 0.34% (Table-4.4.1b). Phosphorous content of 31 short grain rice cultivars varied from 0.23% to 0.39% with the mean value of 0.34±0.041%. Among the short grain local rice cultivars, both Binniphul and Topaboro had the highest phosphorous content (0.39%) but Chinigura had the lowest phosphorous content (0.23%), which was lower than the HYVs. Phosphorous content of HYVs varied from 0.24% to 0.29% (Table-4.4.1c).

Local cultivars of long, medium and short grain rice cultivars had higher phosphorous content than that of HYVs (Figure-4.4.1a). Among the rice cultivars, 5.6% long grain, 6.5% medium grain and 0% short grain had at the level of more than 0.4% phosphorous content; 80.5% long grain, 50% medium grain and 81% short grain had at the level of (0.3-0.4)% phosphorous content; 8.3% long grain, 37% medium grain and 19% short grain had at the level of (0.2-0.3)% phosphorous content as well as 5.6% long grain, 6.5% medium grain and 0% short grain had at the level of less than 0.2% phosphorous content (Figure-4.4.2a).

4.4.2 Calcium content

The calcium content of all tested rice cultivars varied from 0.01% to 0.06%. Cultivars of Kharmao, Joyna and Betudhan had the highest calcium content (0.06%), whereas cultivars of Sadajira Tapl-321 and Murchmut had the lowest calcium content (0.01%). Some local rice cultivars such as Boradudhkalam, Binni-1, Kalimanik, Molladigha, Neda, Pakhisail, Shithabhog, Boylam, Gobcha, Hathazi, Kumragoir, Lalsoru, Ledabinni, Poushmoricha, Dudsail, Laxmikajol, Minki, Nariabochi, Rahikhama and Tulsimala had lower calcium content (0.02)% as same as HYVs such as BR5, BR10, BR11, BR22 and BR23 (Table-4.4.1a,Table-4.4.1b and Table-4.4.1c).

Calcium content of 36 long grain rice cultivars varied from 0.01% to 0.06% with the mean value of 0.03±0.010%. Among the long grain local rice cultivars, Kharmao had the highest calcium content (0.06%) but Sadajira Tapl-321 had the lowest calcium content (0.01%). While, calcium content of HYVs varied from 0.02% to 0.04% (Table-4.4.1a). Calcium content of 62 medium grain rice cultivars varied from 0.02% to 0.06% with the mean value of 0.04±0.011%. Among the medium grain local rice cultivars, Joyna had the highest calcium content (0.06%) but cultivars of Boylam, Gobcha, Hathazi, Kumragoir, Lalsoru, Ledabinni and Poushmoricha had the lowest calcium content (0.02%). HYVs had the range of calcium content of (0.02-0.06)% as same as local rice cultivars (Table-4.4.1b).Calcium content of 31short grain rice cultivars varied from 0.01% to 0.06% with the mean value of 0.03±0.012%. Among the short grain local rice cultivars, Betudhan had the highest calcium content (0.06%) but Murchmut had the lowest calcium content (0.01%). While, calcium content of HYVs varied from 0.02% to 0.05% (Table-4.4.1c).

Local cultivars of long, medium and short grain rice cultivars had lower calcium content than that of HYVs (Figure-4.4.1a). Among the rice cultivars, 39% long grain, 16% medium grain and 42% short grain had at the level of more than 0.04% calcium content; 36% long grain, 68% medium grain and 32% short grain had at the level of (0.03-0.04)% calcium content; 22% long grain, 16% medium grain and 23% short grain had at the level of (0.02-0.03)% calcium content as well as 3% long grain, 0% medium grain and 3% short grain had at the level of less than 0.02% calcium content (Figure-4.4.2a).

4.4.3 Magnesium content

The magnesium content of all tested rice cultivars varied from 0.10% to 0.14%. Cultivars of Neda, Pakhisail, Laxmikajol and Dudsail had the highest magnesium content (0.14%), whereas cultivars of Boradudhkalam, Depa, Dudhkalam, Hatisail, Patnai-231, Kharmao, Nakchi, Kumragoir, Lohasail, Sadamota, Lalbinni, Shamrosh, Gojalgoria, Putidepa, Malagrosa, Chinisagor and Nariabochi had the lowest magnesium content (0.10%). Some local rice cultivars such as Binni-2, Jingasail-1, Kanaibansi, Khorma, Changai, Ganjia, Hashfol, Jhoshua, Michisail, Lalsoru, Jhingasail-2, Kalabinni-2, Kataribhog-232, Kataribhog-1, Uknimadhu, Lalmota, Kataribhog-2, Malsira, Nunia and Paharisailhad lower magnesium content (0.11)% as same as HYVs such as BR4, BRRI dhan33, BRRI dhan39, BRRI dhan40, BRRI dhan41, BRRI dhan44 and BRRI dhan46 (Table-4.4.1a,Table-4.4.1b and Table-4.4.1c).

Magnesium content of 36 long grain rice cultivars varied from 0.10% to 0.14% with the mean value of 0.12±0.012%. Among the long grain local rice cultivars, Neda and Pakhisailhad the highest magnesium content (0.14%) but cultivars of Boradudhkalam, Depa, Dudhkalam, Hatisail, Patnai-231 and Kharmao had the lowest magnesium content (0.10%). While, magnesiumcontent ofHYVs varied from 0.11% to 0.13% (Table-4.4.1a). Magnesium content of 62 medium grain rice cultivars varied from 0.10% to 0.13% with the mean value of 0.12±0.009%. Among the medium grain local rice cultivars, cultivars of Dholagachha, Poushmoricha, Hathazi, Bolonga, Gobcha, Ledabinni and Dadkhani had the highest magnesium content (0.13%) but cultivars of Nakchi, Kumragoir, Lohasail, Sadamota, Lalbinni, Shamrosh, Gojalgoria and Putidepa had the lowest magnesium content (0.10%). While, magnesiumcontent of HYVs varied from 0.11% to 0.13% (Table-4.4.1b). Magnesium content of 31 short grain rice cultivars varied from 0.10% to 0.14% with the mean value of 0.12±0.010%. Among the short grain local rice cultivars, Laxmikajol and Dudsail had the highest magnesium content (0.14%) but cultivars of Malagrosa, Chinisagor and Nariabochi had the lowest magnesium content (0.10%). While, magnesium content of HYVs varied from 0.12% to 0.13% (Table-4.4.1c).

Only long grain local rice cultivars had higher magnesium content than HYVs but other local rice cultivars had the inverse relationship (Figure-4.4.1a). Among the rice cultivars, 5.5% long grain, 0% medium grain and 6.45% short grain had at the level of more than 0.13% magnesium content; 25.0% long grain, 17.7% medium grain and 29.03% short grain had at the level of 0.13% magnesium content; 36.1% long grain, 38.7% medium grain and

48.39% short grain had at the level of 0.12% magnesium content; 16.7% long grain, 30.7% medium grain and 6.45% short grain had at the level of 0.11% magnesium content as well as 16.7% long grain, 12.9% medium grain and 9.68% short grain had at the level of less than 0.11% magnesium content (Figure-4.4.2a).

4.4.4 Nitrogen content

The nitrogen content of all tested rice cultivars varied from 1.1% to 1.8%. Cultivars of Magoibalam and Motichak had the highest nitrogen content (1.8%), whereas cultivars of Kumragoir had the lowest nitrogen content (1.1%) as same as BR23 (Table-4.4.1a and Table-4.4.1b).

Nitrogen content of 36 long grain rice cultivars varied from 1.2% to 1.7% with the mean value of 1.4±0.136%. Among the long grain local rice cultivars, both Molladigha and Neda had the highest nitrogen content (1.7%) but cultivars of Dudhkalam, Kharmao, Kanaibansi, TK deep straw Tapl-773 and Shatahad the lowest nitrogen content (1.2%). While, nitrogen content of HYVs varied from 1.1% to 1.5% (Table-4.4.1a). Nitrogen content of 62 medium grain rice cultivars varied from 1.1% to 1.8% with the mean value of 1.4±0.146%. Among the medium grain local rice cultivars, both Magoibalam and Motichak had the highest nitrogen content (1.8%) but Kumragoir had the lowest nitrogen content (1.1%). While, nitrogen content of HYVsvaried from 1.2% to 1.5% (Table-4.4.1b). Nitrogen content of 31 short grain rice cultivars varied from 1.2% to 1.6% with the mean value of 1.4±0.109%. Among the short grain local rice cultivars, cultivars of Rahikhama, Nurior, Jirakatari-1 and Topaboro had the highest nitrogen content (1.6%) but Tulsimala had the lowest nitrogen content (1.2%). While, nitrogen content of HYVs varied from 1.5% to 1.6% (Table-4.4.1c).

Long grain and medium grain local rice cultivars had higher nitrogen content than HYVs but short grain local rice cultivars had lower nitrogen content than HYVs (Figure-4.4.1a). Among the rice cultivars, 11% long grain, 9.7% medium grain and 16.1% short grain had at the level of more than 1.5% nitrogen content; 6% long grain, 14.5% medium grain and 32.3% short grain had at the level of 1.5% nitrogen content; 33% long grain, 32.3% medium grain and 29% short grain had at the level of 1.4% nitrogen content; 33% long grain, 25.8% medium grain and 19.4% short grain had at the level of 1.3% nitrogen content as well as 17% long grain, 17.7% medium grain and 3.2% short grain had at the level of less than 1.3% nitrogen content (Figure-4.4.2b).

4.4.5 Potassium content

The potassium content of all tested rice cultivars varied from 0.13% to 0.30%. Cultivars ofDadkhani, Laxmikajol and Jirakatari-1 had the highest potassium content (0.30%), whereas cultivars ofNajirsailhad the lowest potassium content (0.13%) as same as BRRI dhan31 (Table-4.4.1b and Table-4.4.1c).

Potassium content of 36 long grain rice cultivars varied from 0.15% to 0.26% with the mean value of 0.20±0.026%. Among the long grain local rice cultivars, Kalabinni-1 had the highest potassium content (0.26%) but Depa had the lowest potassium content (0.15%). While, potassium content of HYVs varied from 0.21% to 0.23% (Table-4.4.1a). Potassium content of 62 medium grain rice cultivars varied from 0.13% to 0.30% with the mean value of 0.21±0.035. Among the medium grain local rice cultivars, Dadkhani had the highest potassium content (0.30%) but Najirsail had the lowest potassium content (0.13%). While, potassium content of HYVs varied from 0.13% to 0.26% (Table-4.4.1b). Potassium content of 31 short grain rice cultivars varied from 0.16% to 0.30% with the mean value of 0.22±0.039%. Among the short grain local rice cultivars, both Laxmikajol and Jirakatari-1 had the highest potassium content (0.30%) but both Murchmut and Gurdoi had the lowest potassium content (0.16%). While, potassium content of HYVs varied from 0.21% to 0.30% (Table-4.4.1c).

Long and short grain local rice cultivars had lower potassium content than HYVs but potassium content of medium grain local rice cultivars had as same as HYVs (Figure-4.4.1b). Among the rice cultivars, 0% long grain, 2% medium grain and 9.7% short grain had at the level of more than 0.29% potassiumcontent; 3% long grain, 11% medium grain and 9.7% short grain had at the level of (0.25-0.29)% potassiumcontent; 64% long grain, 52% medium grain and 54.8% short grain had at the level of (0.20-0.24)% potassiumcontent; 33% long grain, 32% medium grain and 25.8% short grain had at the level of (0.15-0.19)% potassiumcontent as well as 0% long grain, 3% medium grain and 0% short grain had at the level of less than 0.15% potassiumcontent (Figure-4.4.2b).

4.4.6 Sodium content

The sodium content of all tested local rice cultivars varied from 126 ppm to 321 ppm. Cultivar of Gobcha had the highest sodium content (321 ppm), which was lower than the BR5 having the value of sodium content of 332 ppm. On the other hand, cultivars of Lalmota and Surjyamukhisangla had the lowest sodium content (126 ppm) as same as BRRI dhan34 and BRRI dhan39 but higher than the BRRI dhan40 having the value of sodium content of 125 ppm (Table-4.4.1a, Table-4.4.1b and Table-4.4.1c).

Sodium content of 36 long grain rice cultivars varied from 126 ppm to 297 ppm with the mean value of 264±41.3 ppm. Among the long grain local rice cultivars, Redpiebald-219 had the highest sodium content (297 ppm) but Shata had the lowest sodium content (232 ppm). While, sodium content of HYVs varied from 126 ppm to 276 ppm (Table-4.4.1a). Sodium content of 62 medium grain rice cultivars varied from 125 ppm to 321 ppm with the mean value of 252±58.5 ppm. Among the medium grain local rice cultivars, Gobcha had the highest sodium content (321 ppm) but Lalmota had the lowest sodium content (126 ppm). While, sodium content of HYVs varied from 125 ppm to 273 ppm (Table-4.4.1b). Sodium content of 31 short grain rice cultivars varied from 126 ppm to 332 ppm with the mean value of 256±56.8 ppm. Among the short grain local rice cultivars, Jabsira had the highest sodium content (297 ppm) but Surjyamukhisangla had the lowest sodium content (126 ppm). While, sodium content of HYVs varied from 126 ppm to 332 ppm (Table-4.4.1c).

Local cultivars of long, medium and short grain rice cultivars had higher sodium content than that of HYVs (Figure-4.4.1b). Among the rice cultivars, 0% long grain, 3% medium grain and 3% short grain had at the level of more than 300 ppm sodiumcontent; 58% long grain, 60% medium grain and 55% short grain had at the level of (250-300) ppm sodiumcontent; 36% long grain, 19% medium grain and 29% short grain had at the level of (200-250) ppm sodiumcontent as well as 6% long grain, 18% medium grain and 13% short grain had at the level of less than 200 ppm sodiumcontent (Figure-4.4.2b).

4.4.7 Iron content

The iron content of all tested rice cultivars varied from 6 ppm to 10 ppm. Cultivars of Harilaxmi, Dudsar Tapal-146, Kalimanik, Nunia, Paharisail, Dholagachha, Hathazi, Ledabinni, Joyna, Lalmota, Uknimadhu, Binniphul, Chunikanai, Sorukamina and Minkihad the highest iron content (10 ppm), whereascultivars of Lathamona, Shata, Ganjia and Jhoshuahad the lowest iron content (6 ppm) as same as HYVs such as BR22, BR23 and BRRI dhan46 (Table-4.4.1a,Table-4.4.1b and Table-4.4.1c).

Iron content of 36 long grain rice cultivars varied from 6 ppm to 10 ppm with the mean value of 8±1.10 ppm. Among the long grain local rice cultivars, Dudsar Tapal-146, Harilaxmi and Kalimanik had the highest iron content (10 ppm) but Lathamona and Shataboth had the lowest iron content (6 ppm). While, iron content of HYVs varied from 6 ppm to 8 ppm (Table-4.4.1a). Iron content of 62 medium grain rice cultivars varied from 6 ppm to 10 ppm with the mean value of 8±1.06 ppm. Among the medium grain local rice cultivars, Nunia, Paharisail, Dholagachha, Hathazi, Ledabinni, Joyna and Lalmota had the highest iron content (10 ppm) but Ganjia and Jhoshua had the lowest iron content (6 ppm). While, iron content of HYVs varied from 6 ppm to 9 ppm (Table-4.4.1b). Iron content of 31 short grain rice cultivars varied from 7 ppm to 10 ppm with the mean value of 8±1.03 ppm. Among the short grain local rice cultivars, Uknimadhu, Binniphul, Chunikanai, Minkiand Sorukaminahad the highest iron content (10 ppm) but Nariabochi, Michisail, Tulsimala, Nurior, Topaboro and Surjyamukhisangla had the lowest iron content (7 ppm). While, iron content of HYVs varied from 7 ppm to 8 ppm (Table-4.4.1c).

Local cultivars of long, medium and short grain rice cultivars had higher iron content than that of HYVs (Figure-4.4.1b). Among the rice cultivars, 8.3% long grain, 11% medium grain and 16.1% short grain had at the level of more than 9 ppm ironcontent; 19.4% long grain, 26% medium grain and 38.7% short grain had at the level of 9 ppm ironcontent; 30.6% long grain, 39% medium grain and 22.6% short grain had at the level of 8 ppm ironcontent; 33.3% long grain, 18% medium grain and 22.6% short grain had at the level of 7 ppm ironcontent as well as 8.3% long grain, 6% medium grain and 0% short grain had at the level of less than 7 ppm ironcontent (Figure-4.4.2c).

4.4.8 Zinc content

The zinc content of all tested rice cultivars varied from 10 ppm to 20 ppm. Cultivars of DudsarTapal-146, Sadamota,ChamaraandSorukamina had the highest zinc content (20 ppm), whereas cultivars of Dudhkalam,KharmaoandLalbinni had the lowest zinc content (10 ppm) as same as HYVs such as BR11 and BR22 (Table-4.4.1a, Table-4.4.1b and Table-4.4.1c).

Zinc content of 36 long grain rice cultivars varied from 10 ppm to 20 ppm with the mean value of 16±2.77 ppm. Among the long grain local rice cultivars, Dudsar Tapal-146had the highest zinc content (20 ppm) but both Dudhkalam and Kharmao had the lowest zinc content (10 ppm). While, zinc content of HYVs varied from 12 ppm to 19 ppm (Table-4.4.1a). Zinc content of 62 medium grain rice cultivars varied from 10 ppm to 20 ppm with the mean value of 16±2.86 ppm. Among the medium grain local rice cultivars, both Sadamota and Chamara had the highest zinc content (20 ppm) but Lalbinni had the lowest zinc content (10 ppm). While, zinc content of HYVs varied from 10 ppm to 19 ppm(Table-

4.4.1b). Zinc content of 31 short grain rice cultivars varied from 11 ppm to 20 ppm with the mean value of 16±2.40 ppm. Among the short grain local rice cultivars, Sorukamina had the highest zinc content (20 ppm) but Betudhan had the lowest zinc content (11 ppm).While, zinc content of HYVs varied from 17 ppm to 18 ppm (Table-4.4.1c).

Medium grain local rice cultivars had higher zinc content than HYVs. Both long grain local rice cultivars and HYVs had the similar zinc content but short grain local rice cultivars had lower zinc content than that of HYVs (Figure-4.4.1b). Among the rice cultivars, 2.78% long grain, 3% medium grain and 3% short grain had at the level of more than 19 ppm zinccontent; 25% long grain, 34% medium grain and 26% short grain had at the level of (18-19) ppm zinccontent; 27.78% long grain, 23% medium grain and 39% short grain had at the level of (16-17) ppm zinccontent; 38.89% long grain, 35% medium grain and 32% short grain had at the level of (11-15) ppm zinccontent as well as 5.56% long grain, 5% medium grain and 0% short grain had at the level of less than 11 ppm zinccontent (Figure-4.4.2c).

4.4.9 Correlation of mineral elements

Pearson correlation coefficients for relationships had among various brown rice mineral elements of different long grain rice cultivars. Calcium content was negatively correlated with phosphorous content. Magnesium content was highly significant and negatively correlated with calcium content ($r = -0.497$, $p<0.01$) but it was positively correlated with phosphorous content. Nitrogen content was positively correlated with phosphorous and magnesium content but it was negatively correlated with calcium content. Potassium content was significant and negatively correlated with phosphorous content ($r = -0.352$, $p<0.05$). Potassium content was positively correlated with magnesium content but it was negatively correlated with calcium and nitrogen content. Sodium content was highly significant and positively correlated with phosphorous content ($r=0.642$, $p<0.01$); it was highly significant and negatively correlated with potassium content ($r = -0.455$, $p<0.01$); it was positively correlated with calcium content but it was negatively correlated with magnesium and nitrogen content. Iron was positively correlated with phosphorous, calcium, magnesium, nitrogen and sodium content but it was negatively correlated with potassium content. Zinc content was highly significant and positively correlated with nitrogen content ($r=0.597$, $p<0.01$); it was significant and positively correlated with iron content ($r=0.342$, $p<0.05$); it was significant and negatively correlated with potassium content ($r = -0.404$, $p<0.05$); it was positively correlated with phosphorous and magnesium contentbut it was negatively correlated with calcium and sodium content (Table-4.4.2a).

Pearson correlation coefficients for relationships had among various brown rice mineral elements of different medium grain rice cultivars. Calcium content was significant and negatively correlated with phosphorous content (r= -0.307, p<0.05). Magnesium content was positively correlated with phosphorous content but negatively correlated with calcium content. Nitrogen content was significant and positively correlated with magnesium content (r=0.307, p<0.05) as well as it was positively correlated with phosphorous and calcium content. Potassium content was highly significant and positively correlated with both magnesium content (r=0.365, p<0.01) and nitrogen content (r=0.471, p<0.01); it was positively correlated with phosphorous content but negatively correlated with calcium content. Sodium content was highly significant and positively correlated with phosphorous content (r=0.431, p<0.01) but it was negatively correlated with calcium, magnesium, nitrogen and potassium content. Iron content was significant and positively correlated with nitrogen content (r=0.297, p<0.05) as well as it was positively correlated with phosphorous, calcium, magnesium, potassium and sodium content. Zinc content was highly significant and positively correlated with nitrogen content (r=0.487, p<0.01); it was significant and positively correlated with iron content (r=0.291, p<0.05) as well as it was positively correlated with phosphorous, calcium, potassium and sodium content but negatively correlated with magnesium content (Table-4.4.2b).

Pearson correlation coefficients for relationships had among various brown rice mineral elements of different short grain rice cultivars. Calcium content was negatively correlated with phosphorous content. Magnesium content was positively correlated with phosphorous content but negatively correlated with calcium content. Nitrogen content was highly significant and positively correlated with magnesium content (r=0.461, p<0.01) as well as it was positively correlated with phosphorous and calcium content. Potassium content was significant and positively correlated with both magnesium (r=0.370, p<0.05) and nitrogen content (r=0.423, p<0.05) as well as it was positively correlated with calcium content but negatively correlated with phosphorous content. Sodium content was significant and negatively correlated with calcium content (r= -0.405, p<0.05) as well as it was positively correlated with phosphorous content but negatively correlated with magnesium, nitrogen and potassium content. Iron content was positively correlated with calcium, magnesium and sodium content but negatively correlated with phosphorous, nitrogen and potassium content. Zinc content was positively correlated with phosphorous, calcium, nitrogen and iron content but negatively correlated with magnesium, potassium and sodium content (Table-4.4.2c).

The differences in mineral contents among cultivars might be due to different varietal and environmental involved.

4.4.10 Cluster analysis of mineral elements

Dendrogram of mineral elements (phosphorous, calcium, magnesium, nitrogen, potassium, sodium, ironand zinc)for all rice cultivars (local cultivars and HYVs) based clustering provided 2 clusters: one cluster at level below 5 and another cluster at level 25. All mineral elements were represented in cluster-1 at level below 5 except nitrogen element. On the other hand, nitrogen element was represented in cluster-2 at level 25. So, phosphorous, calcium, magnesium, potassium, sodium, iron and zinc content had very close relationship with each other but nitrogen had very week relationship with those elements. This cluster indicated that all mineral elements accumulated very few quantity in rice than nitrogencontent (Figure-4.4.3).

Table-4.4.1a:Mean performance of minerals content for 36 long grain brown rice cultivars

Sl. No.	Cultivars	Phosphorous (%)	Calcium (%)	Magnesium (%)	Nitrogen (%)	Potassium (%)	Sodium (ppm)	Iron (ppm)	Zinc (ppm)
1	Athabinni	0.33±0.013	0.03±0.014	0.13±0.005	1.4±0.017	0.22±0.009	245±5.31	9±0.00	14±2.59
2	Bhorochalam	0.38±0.029	0.04±0.017	0.12±0.004	1.4±0.044	0.16±0.011	293±1.21	9±0.00	18±1.00
3	Binni-1	0.35±0.006	0.02±0.010	0.13±0.007	1.4±0.032	0.23±0.010	238±7.35	7±1.73	16±1.71
4	Binni-2	0.32±0.009	0.04±0.012	0.11±0.008	1.4±0.047	0.20±0.017	235±0.84	7±1.73	18±2.65
5	Boradudhkalam	0.35±0.007	0.02±0.004	0.10±0.004	1.3±0.048	0.21±0.007	290±1.34	7±1.15	12±2.08
6	Cylindrical Tapi-629	0.35±0.016	0.04±0.011	0.12±0.003	1.3±0.039	0.20±0.009	296±1.09	8±1.53	16±2.52
7	Depa	0.32±0.054	0.05±0.020	0.10±0.026	1.3±0.039	0.15±0.052	291±1.00	9±3.06	15±2.31
8	Dudhkalam	0.33±0.010	0.03±0.007	0.10±0.007	1.2±0.057	0.22±0.015	287±3.15	7±0.58	10±1.53
9	Dudsar Tapal-146	0.34±0.017	0.05±0.025	0.12±0.004	1.4±0.014	0.17±0.006	295±2.74	10±1.73	20±2.37
10	Gohatibinni	0.33±0.015	0.03±0.013	0.13±0.003	1.4±0.085	0.21±0.011	243±0.93	8±1.73	18±2.00
11	Harilaxmi	0.35±0.014	0.03±0.004	0.12±0.006	1.5±0.025	0.16±0.014	288±0.77	10±3.46	18±0.63
12	Hatisail	0.34±0.024	0.03±0.004	0.10±0.003	1.4±0.028	0.20±0.004	292±0.25	9±0.58	19±1.98
13	Jingasail-1	0.35±0.008	0.04±0.010	0.11±0.006	1.4±0.034	0.23±0.010	293±3.14	8±3.46	17±0.58
14	Joalbagh	0.43±0.007	0.03±0.005	0.12±0.005	1.6±0.027	0.19±0.008	288±1.29	7±1.53	17±0.58
15	Jol	0.39±0.010	0.04±0.014	0.12±0.002	1.6±0.017	0.18±0.012	295±0.47	7±2.08	19±1.18
16	Kalabinni-1	0.33±0.013	0.03±0.011	0.13±0.002	1.4±0.046	0.26±0.039	243±1.14	9±0.00	14±2.65
17	Kalimanik	0.29±0.013	0.02±0.003	0.13±0.004	1.3±0.030	0.23±0.015	243±1.25	10±1.73	15±1.53
18	Kanaibansi	0.35±0.018	0.04±0.009	0.11±0.002	1.2±0.030	0.19±0.008	287±3.02	7±1.15	13±2.50
19	Karailadhan	0.30±0.014	0.03±0.007	0.13±0.001	1.3±0.045	0.22±0.010	242±3.84	8±1.73	13±1.66
20	Kharmao	0.35±0.012	0.06±0.040	0.10±0.007	1.2±0.031	0.21±0.005	288±3.14	7±1.53	10±2.65
21	Khorma	0.33±0.009	0.04±0.011	0.11±0.003	1.3±0.019	0.23±0.006	294±5.29	8±1.53	12±1.00
22	Lathamona	0.32±0.025	0.03±0.009	0.13±0.008	1.4±0.018	0.22±0.006	242±1.83	6±3.21	17±0.70
23	Molladigha	0.35±0.013	0.02±0.008	0.12±0.009	1.7±0.051	0.18±0.007	287±1.86	9±1.36	17±1.03
24	Neda	0.39±0.016	0.02±0.004	0.14±0.006	1.7±0.083	0.22±0.006	247±4.01	8±0.00	17±2.08
25	Pakhisail	0.34±0.016	0.02±0.004	0.14±0.009	1.3±0.035	0.22±0.007	246±1.13	8±1.53	12±0.99
26	Patnai-231	0.30±0.014	0.04±0.006	0.10±0.008	1.3±0.081	0.21±0.009	290±4.79	7±1.15	13±2.65
27	Redpiebald-219	0.34±0.011	0.03±0.005	0.12±0.005	1.3±0.023	0.19±0.012	297±1.86	8±1.73	17±2.08
28	Sadajira Tapl-321	0.36±0.015	0.01±0.008	0.12±0.006	1.3±0.038	0.17±0.010	291±1.18	9±3.06	16±1.15
29	Shata	0.35±0.028	0.03±0.007	0.13±0.002	1.2±0.029	0.23±0.015	232±5.86	6±0.58	11±1.15
30	Shithabhog	0.31±0.015	0.02±0.005	0.12±0.008	1.4±0.039	0.21±0.011	240±4.87	7±1.15	19±0.65
31	T.R.Aman	0.41±0.006	0.04±0.012	0.12±0.007	1.3±0.025	0.16±0.004	292±0.44	8±1.53	18±1.53
32	TK deep straw Tapl-773	0.36±0.021	0.03±0.003	0.12±0.009	1.2±0.024	0.16±0.005	294±1.42	7±1.50	15±1.53
33	BR23	0.28±0.008	0.02±0.007	0.13±0.006	1.1±0.016	0.23±0.008	238±0.50	6±0.00	15±2.11
34	BRRI dhan30	0.19±0.012	0.04±0.013	0.12±0.002	1.4±0.046	0.21±0.007	129±1.19	8±1.73	16±1.53
35	BRRI dhan39	0.22±0.005	0.03±0.010	0.11±0.003	1.5±0.030	0.22±0.011	126±2.00	8±2.52	19±1.00
36	BRRI dhan41	0.19±0.014	0.04±0.012	0.11±0.007	1.3±0.047	0.21±0.012	276±2.95	7±1.15	12±0.73
Range		**0.19-0.43**	**0.01-0.06**	**0.10-0.14**	**1.1-1.7**	**0.15-0.26**	**126-297**	**6-10**	**10-20**
Mean ± SD		**0.33±0.051**	**0.03±0.010**	**0.12±0.012**	**1.4±0.136**	**0.20±0.026**	**264±41.3**	**8±1.10**	**16±2.77**
CV%		**15**	**32**	**10**	**10**	**13**	**16**	**14**	**18**
SE (Standard error)		**0.8525-02**	**0.6684-02**	**0.4072-02**	**0.1803-01**	**0.8416-02**	**1.70439**	**0.9716**	**0.9945**
LSD (0.05)		**0.2404-01**	**0.1885-01**	**0.1148-01**	**0.5086-01**	**0.2373-01**	**4.8068**	**2.740**	**2.8049**

Table-4.4.1b:Mean performance of minerals content for 62 medium grain brown rice cultivars

Sl. No.	Cultivars	Phosphorous (%)	Calcium (%)	Magnesium (%)	Nitrogen (%)	Potassium (%)	Sodium (ppm)	Iron (ppm)	Zinc (ppm)
1	Bariksail	0.39±0.007	0.03±0.006	0.12±0.004	1.3±0.044	0.18±0.014	291±1.76	8±1.73	15±2.08
2	Bolonga	0.33±0.009	0.03±0.008	0.13±0.005	1.5±0.081	0.26±0.042	245±2.15	7±1.53	19±0.51
3	Boylam	0.26±0.011	0.02±0.013	0.12±0.006	1.7±0.011	0.28±0.016	267±1.89	8±0.58	18±1.00
4	Chamara	0.32±0.008	0.04±0.012	0.12±0.003	1.4±0.028	0.19±0.007	291±3.62	8±3.21	20±2.33
5	Changai	0.25±0.025	0.03±0.010	0.11±0.005	1.4±0.028	0.23±0.022	128±1.35	9±0.00	17±0.57
6	Dadkhani	0.37±0.012	0.03±0.012	0.13±0.006	1.5±0.028	0.30±0.013	312±2.97	7±1.21	19±2.83
7	Dholagachha	0.29±0.006	0.04±0.004	0.13±0.008	1.3±0.026	0.23±0.014	244±1.58	10±1.73	13±2.13
8	Ganjia	0.39±0.006	0.03±0.005	0.11±0.006	1.2±0.041	0.20±0.013	298±0.83	6±0.58	12±1.03
9	Gobcha	0.35±0.008	0.02±0.006	0.13±0.010	1.5±0.045	0.23±0.016	321±9.25	8±1.00	18±1.83
10	Gojalgoria	0.21±0.013	0.03±0.012	0.10±0.005	1.3±0.023	0.19±0.011	291±0.49	7±1.73	16±1.53
11	Hashfol	0.30±0.014	0.05±0.022	0.11±0.014	1.2±0.064	0.18±0.007	287±2.30	7±1.53	11±2.76
12	Hathazi	0.32±0.017	0.02±0.003	0.13±0.003	1.5±0.015	0.29±0.012	241±4.70	10±1.73	17±1.83
13	Hijli	0.37±0.023	0.03±0.007	0.12±0.006	1.3±0.039	0.18±0.011	293±0.56	9±0.58	14±1.16
14	Jhingasail-2	0.20±0.013	0.05±0.018	0.11±0.007	1.3±0.046	0.20±0.014	186±1.11	8±1.21	14±1.53
15	Jhoshua	0.32±0.008	0.04±0.010	0.11±0.002	1.2±0.055	0.22±0.018	287±1.03	6±0.51	19±1.00
16	Joyna	0.20±0.006	0.06±0.015	0.12±0.012	1.4±0.043	0.22±0.015	271±1.35	10±1.73	16±0.50
17	Kajalsail	0.36±0.009	0.04±0.011	0.12±0.004	1.3±0.030	0.16±0.015	296±0.88	9±0.23	14±0.84
18	Kalabinni-2	0.37±0.011	0.04±0.007	0.11±0.008	1.3±0.041	0.21±0.009	290±0.81	9±3.06	12±1.71
19	Kalisayta	0.27±0.016	0.05±0.011	0.12±0.007	1.7±0.039	0.28±0.013	215±1.84	9±0.58	18±0.58
20	Kanaklata	0.28±0.008	0.04±0.010	0.12±0.011	1.4±0.063	0.20±0.022	195±1.15	9±0.00	14±0.00
21	Kataribhog-232	0.24±0.004	0.04±0.004	0.11±0.005	1.6±0.058	0.20±0.016	225±0.18	8±3.06	14±0.50
22	Kataribhog-1	0.34±0.011	0.03±0.006	0.11±0.011	1.3±0.029	0.19±0.006	290±3.30	7±1.73	18±2.97
23	Kataribhog-2	0.28±0.007	0.03±0.011	0.11±0.004	1.5±0.022	0.20±0.018	127±0.93	8±1.42	15±2.20
24	Kumragoir	0.25±0.004	0.02±0.004	0.10±0.002	1.1±0.080	0.18±0.008	291±1.72	7±1.73	12±2.71
25	Lalbinni	0.28±0.008	0.04±0.014	0.10±0.006	1.2±0.044	0.17±0.005	293±3.88	8±1.25	10±1.00
26	Lalmota	0.31±0.012	0.03±0.015	0.11±0.003	1.4±0.046	0.22±0.024	126±1.55	10±1.73	17±1.89
27	Lalsoru	0.35±0.014	0.02±0.004	0.11±0.003	1.2±0.037	0.20±0.007	288±0.95	8±1.53	17±1.29
28	Ledabinni	0.36±0.019	0.02±0.007	0.13±0.006	1.4±0.030	0.26±0.039	245±1.70	10±1.53	18±2.08
29	Lohasail	0.28±0.009	0.03±0.009	0.10±0.007	1.2±0.029	0.19±0.014	295±0.29	7±1.53	11±2.08
30	Magoibalam	0.41±0.048	0.04±0.010	0.12±0.003	1.8±0.032	0.22±0.007	290±3.89	8±0.00	17±2.86
31	Maloti	0.40±0.011	0.03±0.008	0.12±0.005	1.4±0.041	0.18±0.013	289±0.70	9±0.40	19±1.63
32	Malsira	0.37±0.012	0.04±0.011	0.11±0.011	1.4±0.058	0.22±0.008	296±2.91	9±0.00	17±1.89
33	Motichak	0.36±0.006	0.03±0.011	0.12±0.002	1.8±0.051	0.28±0.012	127±1.89	8±0.00	18±1.00
34	Najirsail	0.30±0.011	0.05±0.014	0.12±0.010	1.3±0.065	0.13±0.005	129±0.97	7±3.06	12±1.34
35	Nakchi	0.24±0.012	0.03±0.006	0.10±0.003	1.3±0.048	0.17±0.015	295±1.47	8±1.53	18±2.59

Sl. No.	Cultivars	Phosphorous (%)	Calcium (%)	Magnesium (%)	Nitrogen (%)	Potassium (%)	Sodium (ppm)	Iron (ppm)	Zinc (ppm)
36	Nizersail	0.40±0.010	0.03±0.007	0.12±0.002	1.4±0.016	0.18±0.009	290±5.82	9±0.00	18±1.54
37	Nunia	0.33±0.007	0.03±0.003	0.11±0.002	1.4±0.050	0.22±0.018	287±1.45	10±1.63	16±0.00
38	Paharisail	0.40±0.005	0.04±0.011	0.11±0.013	1.3±0.033	0.21±0.005	298±2.56	10±1.73	15±1.37
39	Pakibiroin	0.38±0.009	0.04±0.006	0.12±0.007	1.5±0.027	0.18±0.016	296±2.24	8±1.53	15±2.39
40	Poushmoricha	0.30±0.011	0.02±0.009	0.13±0.004	1.3±0.051	0.22±0.007	246±1.96	8±1.53	12±1.03
41	Putidepa	0.37±0.011	0.05±0.015	0.10±0.002	1.4±0.045	0.23±0.013	293±2.43	9±0.58	19±1.92
42	Rajamora	0.32±0.014	0.03±0.008	0.12±0.011	1.6±0.058	0.21±0.013	292±2.59	9±1.53	19±0.52
43	Rangabinni	0.29±0.015	0.04±0.005	0.12±0.011	1.4±0.037	0.20±0.017	260±8.95	7±1.53	17±0.74
44	Sadamota	0.27±0.009	0.04±0.013	0.10±0.006	1.5±0.046	0.18±0.005	288±2.94	9±1.73	20±0.90
45	Shamrosh	0.31±0.022	0.04±0.009	0.10±0.004	1.2±0.035	0.20±0.014	294±5.80	9±3.06	19±2.66
46	Somondori	0.39±0.009	0.03±0.004	0.12±0.004	1.4±0.007	0.17±0.012	294±3.89	9±0.50	18±2.08
47	Tilkapur	0.34±0.007	0.03±0.008	0.12±0.005	1.2±0.045	0.16±0.008	289±3.23	8±3.21	18±0.61
48	Tilokkajal	0.39±0.013	0.04±0.009	0.12±0.007	1.5±0.062	0.17±0.011	296±3.50	9±2.52	17±2.30
49	BR4	0.34±0.009	0.03±0.009	0.11±0.004	1.3±0.033	0.22±0.007	231±2.72	7±1.15	12±1.11
50	BR10	0.29±0.014	0.02±0.011	0.13±0.005	1.3±0.048	0.22±0.010	236±1.84	7±1.06	11±0.58
51	BR11	0.28±0.005	0.02±0.007	0.13±0.007	1.3±0.032	0.21±0.017	234±2.09	8±1.53	10±0.58
52	BR22	0.30±0.015	0.02±0.006	0.13±0.009	1.2±0.030	0.23±0.013	235±4.42	6±0.81	10±1.00
53	BR25	0.32±0.012	0.03±0.012	0.13±0.002	1.4±0.038	0.26±0.039	230±2.73	8±2.08	17±1.06
54	BRRI dhan31	0.17±0.006	0.04±0.015	0.12±0.001	1.4±0.035	0.13±0.002	267±3.06	8±2.16	19±2.27
55	BRRI dhan32	0.20±0.015	0.06±0.017	0.12±0.013	1.4±0.042	0.18±0.041	268±3.44	8±1.73	15±1.23
56	BRRI dhan33	0.19±0.002	0.05±0.007	0.11±0.005	1.4±0.020	0.23±0.020	272±2.36	9±0.58	19±2.08
57	BRRI dhan37	0.22±0.006	0.06±0.009	0.12±0.011	1.5±0.047	0.20±0.013	270±1.91	8±1.15	18±1.53
58	BRRI dhan38	0.21±0.005	0.06±0.010	0.12±0.006	1.4±0.052	0.21±0.006	127±2.02	8±1.73	16±0.57
59	BRRI dhan40	0.19±0.003	0.03±0.012	0.11±0.003	1.4±0.023	0.21±0.013	125±1.01	8±1.59	17±1.11
60	BRRI dhan44	0.19±0.006	0.04±0.007	0.11±0.004	1.4±0.058	0.21±0.011	129±1.29	8±1.93	18±2.50
61	BRRI dhan46	0.21±0.014	0.03±0.008	0.11±0.006	1.2±0.053	0.17±0.037	129±1.71	6±0.52	15±1.64
62	BRRI dhan49	0.22±0.010	0.03±0.006	0.12±0.011	1.3±0.048	0.22±0.017	273±2.26	8±1.53	12±1.23
Range		**0.17-0.41**	**0.02-0.06**	**0.10-0.13**	**1.1-1.8**	**0.13-0.30**	**125-321**	**6-10**	**10-20**
Mean ± SD		**0.30±0.066**	**0.04±0.011**	**0.12±0.009**	**1.4±0.146**	**0.21±0.035**	**252±58.5**	**8±1.06**	**16±2.86**
CV%		**22**	**31**	**8**	**11**	**17**	**23**	**13**	**18**
SE (Standard error)		**0.6536-02**	**0.5630-02**	**0.3952-02**	**0.1712-01**	**0.9808-02**	**1.690**	**0.8382**	**0.8040**
LSD (0.05)		**0.1829-01**	**0.1576-01**	**0.1106-01**	**0.4794-01**	**0.2745-01**	**4.731**	**2.346**	**2.2508**

Table-4.4.1c:Mean performance of minerals content for 31 short grain brown rice cultivars

Sl. No.	Cultivars	Phosphorous (%)	Calcium (%)	Magnesium (%)	Nitrogen (%)	Potassium (%)	Sodium (ppm)	Iron (ppm)	Zinc (ppm)
1	Baoijhaki	0.34±0.014	0.03±0.011	0.13±0.008	1.4±0.018	0.23±0.017	243±1.62	9±3.21	16±0.58
2	Betudhan	0.34 ±0.020	0.06±0.010	0.12±0.008	1.3±0.083	0.22±0.021	293±3.04	8±1.53	11±1.75
3	Binniphul	0.39 ±0.027	0.04±0.012	0.12±0.003	1.5±0.023	0.19±0.005	292±4.40	10±1.15	19±2.15
4	Chinisagor	0.33± 0.024	0.03±0.011	0.10±0.007	1.3±0.038	0.20±0.01	293±3.21	9±0.00	17±2.08
5	Chinigura	0.23±0.021	0.05±0.007	0.12±0.005	1.4±0.031	0.26±0.042	128±0.63	8±1.53	17±1.40
6	Chunikanai	0.29 ±0.041	0.05±0.005	0.12±0.004	1.4±0.045	0.20±0.011	291±2.41	10±1.73	16±1.34
7	Dudsail	0.36±0.006	0.02±0.009	0.14±0.002	1.5±0.042	0.21±0.012	245±2.39	9±3.00	13±2.08
8	Gurdoi	0.36±0.009	0.04±0.010	0.12±0.006	1.4±0.023	0.16±0.013	291±1.65	9±0.00	16±1.34
9	Jabsira	0.35 ±0.012	0.03±0.006	0.12±0.008	1.3±0.035	0.18±0.003	297±0.95	9±3.00	14±0.79
10	Jirakatari-1	0.35±0.015	0.04±0.016	0.13±0.013	1.6±0.011	0.30±0.008	242±1.68	9±0.50	14±0.58
11	Jirakatari-2	0.33±0.012	0.04±0.014	0.12±0.001	1.5±0.058	0.22±0.020	263±3.92	8±2.76	12±2.15
12	Kalasaru	0.36±0.013	0.03±0.011	0.13±0.005	1.5±0.041	0.23±0.017	244±1.05	8±1.73	12±2.08
13	Kalijira	0.35±0.015	0.05±0.013	0.12±0.002	1.5±0.056	0.20±0.015	129±1.85	9±1.53	18±2.78
14	Khasha	0.36± 0.055	0.03±0.006	0.12±0.006	1.4±0.030	0.20±0.10	293±2.54	9±0.58	19±2.59
15	Lalsaru	0.35±0.019	0.03±0.008	0.13±0.001	1.4±0.044	0.21±0.009	244±3.57	9±0.58	18±1.17
16	Laxmikajol	0.37±0.010	0.02±0.004	0.14±0.011	1.5±0.067	0.30±0.007	241±2.79	8±1.63	12±1.53
17	Malagrosa	0.27 ±0.016	0.03±0.005	0.10±0.003	1.3±0.035	0.21±0.008	288±1.94	9±3.00	14±1.53
18	Michisail	0.38± 0.027	0.05±0.011	0.11±0.010	1.5±0.061	0.24±0.01	287±3.91	7±1.53	19±1.37
19	Minki	0.34±0.0.14	0.02±0.006	0.13±0.003	1.4±0.024	0.22±0.003	243±1.25	10±1.73	17±1.17
20	Murchmut	0.28 ±0.025	0.01±0.003	0.12±0.009	1.3±0.031	0.16±0.011	293±4.81	9±3.06	13±0.57
21	Nariabochi	0.31± 0.025	0.02±0.005	0.10±0.004	1.3±0.085	0.19±0.01	295±1.83	7±1.50	16±0.90
22	Nurior	0.37±0.017	0.03±0.007	0.12±0.004	1.6±0.043	0.17±0.011	291±3.20	7±0.58	16±1.76
23	Pajam	0.32±0.012	0.04±0.006	0.12±0.007	1.5±0.037	0.21±0.009	211±1.73	8±1.73	17±1.80
24	Rahikhama	0.37 ±0.010	0.02±0.005	0.13±0.002	1.6±0.029	0.19±0.011	296±3.45	9±1.53	15±1.11
25	Sorukamina	0.32 ±0.020	0.03±0.003	0.13±0.007	1.4±0.033	0.20±0.006	295±4.00	10±1.15	20±2.81
26	Surjyamukhisangla	0.35±0.016	0.04±0.012	0.12±0.011	1.5±0.083	0.28±0.014	126±0.34	7±3.06	18±1.06
27	Topaboro	0.39±0.007	0.03±0.005	0.13±0.007	1.6±0.054	0.28±0.020	238±2.50	7±0.58	17±1.53
28	Tulsimala	0.37 ±0.018	0.02±0.005	0.12±0.009	1.2±0.030	0.18±0.009	290±2.51	7±1.53	16±1.28
29	Uknimadhu	0.35 ±0.020	0.04±0.007	0.11±0.002	1.4±0.026	0.21±0.011	290±3.32	10±1.36	18±1.76
30	BR5	0.29±0.009	0.02±0.006	0.13±0.005	1.5±0.073	0.30±0.008	332±3.70	7±1.15	18±2.08
31	BRRI dhan34	0.24±0.012	0.05±0.008	0.12±0.003	1.6±0.021	0.21±0.006	126±0.63	8±0.58	17±1.00
Range		**0.23-0.39**	**0.01-0.06**	**0.10-0.14**	**1.2-1.6**	**0.16-0.30**	**126-332**	**7-10**	**11-20**
Mean ± SD		**0.34±0.041**	**0.03±0.012**	**0.12±0.010**	**1.4±0.109**	**0.22±0.039**	**256±56.8**	**8±1.03**	**16±2.40**
CV%		**12**	**36**	**8**	**8**	**18**	**22**	**12**	**15**
SE (Standard error)		**0.1382-01**	**0.4622-02**	**0.3632-02**	**0.1400-01**	**0.8080-02**	**1.5646**	**0.8754**	**0.7347**
LSD (0.05)		**0.3910-01**	**0.1307-01**	**0.1027-01**	**0.3961-01**	**0.2285-01**	**4.4257**	**2.4764**	**2.0782**

Table-4.4.2a: The Pearson correlation coefficient for mineral elements on the basis of different long grain rice cultivars

Correlations

Parameters	**Phosphorous(%)**	**Calcium (%)**	**Magnesium (%)**	**Nitrogen (%)**	**Potassium (%)**	**Sodium (ppm)**	**Iron (ppm)**
Phosphorous (%)	1						
Calcium (%)	-.053	1					
Magnesium (%)	.125	-.497**	1				
Nitrogen (%)	.222	-.164	.223	1			
Potassium (%)	-.352*	-.255	.252	-.121	1		
Sodium (ppm)	.642**	.196	-.311	-.116	-.455**	1	
Iron (ppm)	.049	.003	.075	.310	-.303	.114	1
Zinc (ppm)	.157	-.069	.175	.597**	-.404*	-.098	.342*

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table-4.4.2b: The Pearson correlation coefficient for mineral elements on the basis of different medium grain rice cultivars

Correlations

Parameters	**Phosphorous (%)**	**Calcium (%)**	**Magnesium (%)**	**Nitrogen (%)**	**Potassium (%)**	**Sodium(ppm)**	**Iron (ppm)**
Phosphorous (%)	1						
Calcium (%)	-.307*	1					
Magnesium (%)	.206	-.205	1				
Nitrogen (%)	.088	.116	.307*	1			
Potassium (%)	.088	-.228	.365**	.471**	1		
Sodium (ppm)	.431**	-.065	-.045	-.158	-.133	1	
Iron (ppm)	.155	.147	.071	.297*	.151	.056	1
Zinc (ppm)	.073	.115	-.008	.487**	.205	.084	.291*

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table-4.4.2c: The Pearson correlation coefficient for mineral elements on the basis of different short grain rice cultivars

Correlations

Parameters	**Phosphorous (%)**	**Calcium (%)**	**Magnesium (%)**	**Nitrogen (%)**	**Potassium (%)**	**Sodium (ppm)**	**Iron (ppm)**
Phosphorous (%)	1						
Calcium (%)	-.147	1					
Magnesium (%)	.279	-.243	1				
Nitrogen (%)	.220	.173	.461**	1			
Potassium (%)	-.011	.100	.370*	.423*	1		
Sodium (ppm)	.281	-.405*	-.152	-.353	-.320	1	
Iron (ppm)	-.038	.018	.083	-.173	-.346	.160	1
Zinc (ppm)	.023	.143	-.191	.094	-.032	-.119	.101

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

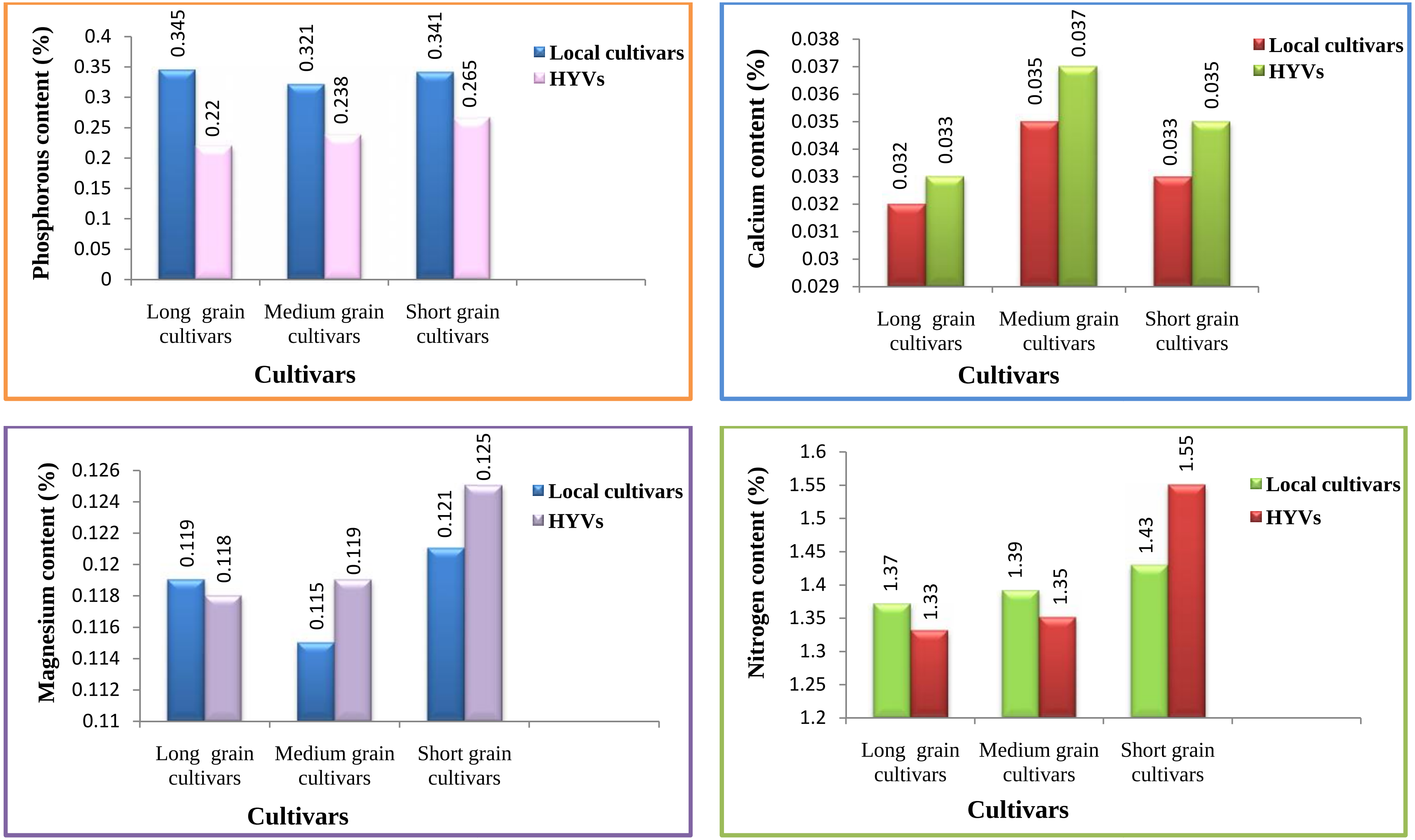

Figure-4.4.1a: Comparison of phosphorous, calcium, magnesium and nitrogen content for different local rice cultivars and HYVs

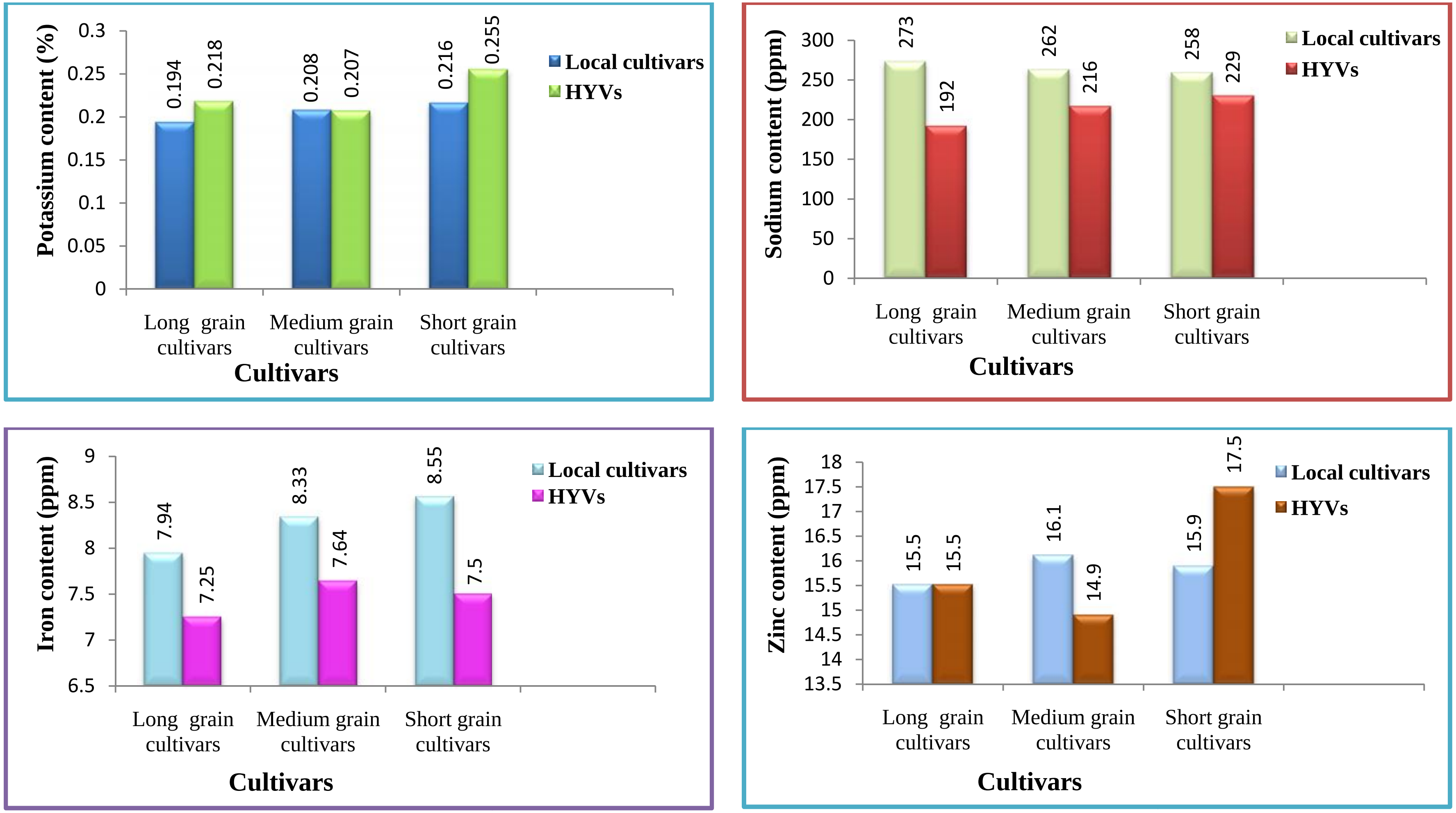

Figure-4.4.1b: Comparison of potassium, sodium, iron and zinc content for different local rice cultivars and HYVs

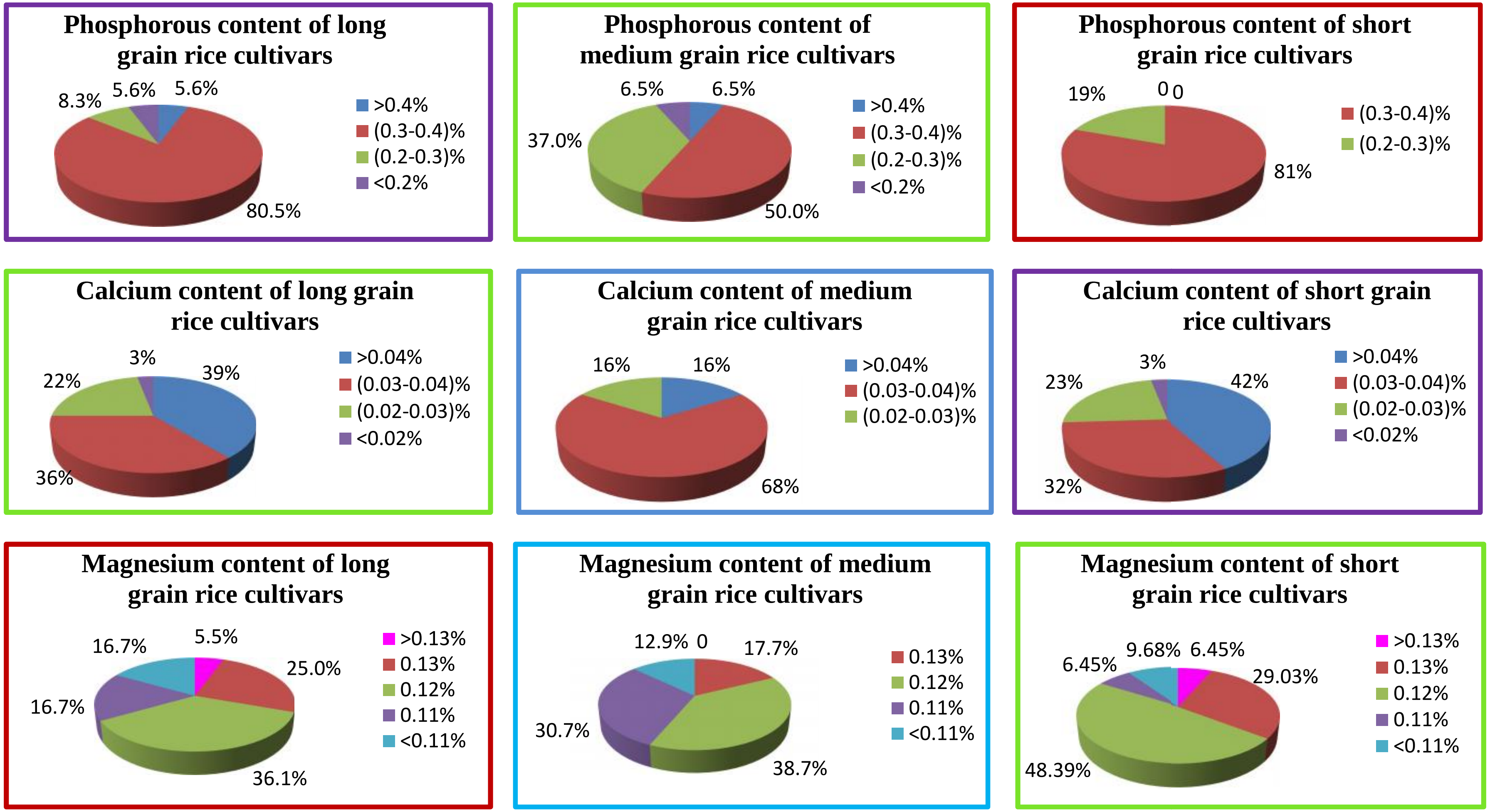

Figure-4.4.2a: Frequency distribution of phosphorous, calcium and magnesium contentfor long, medium and short grain rice cultivars

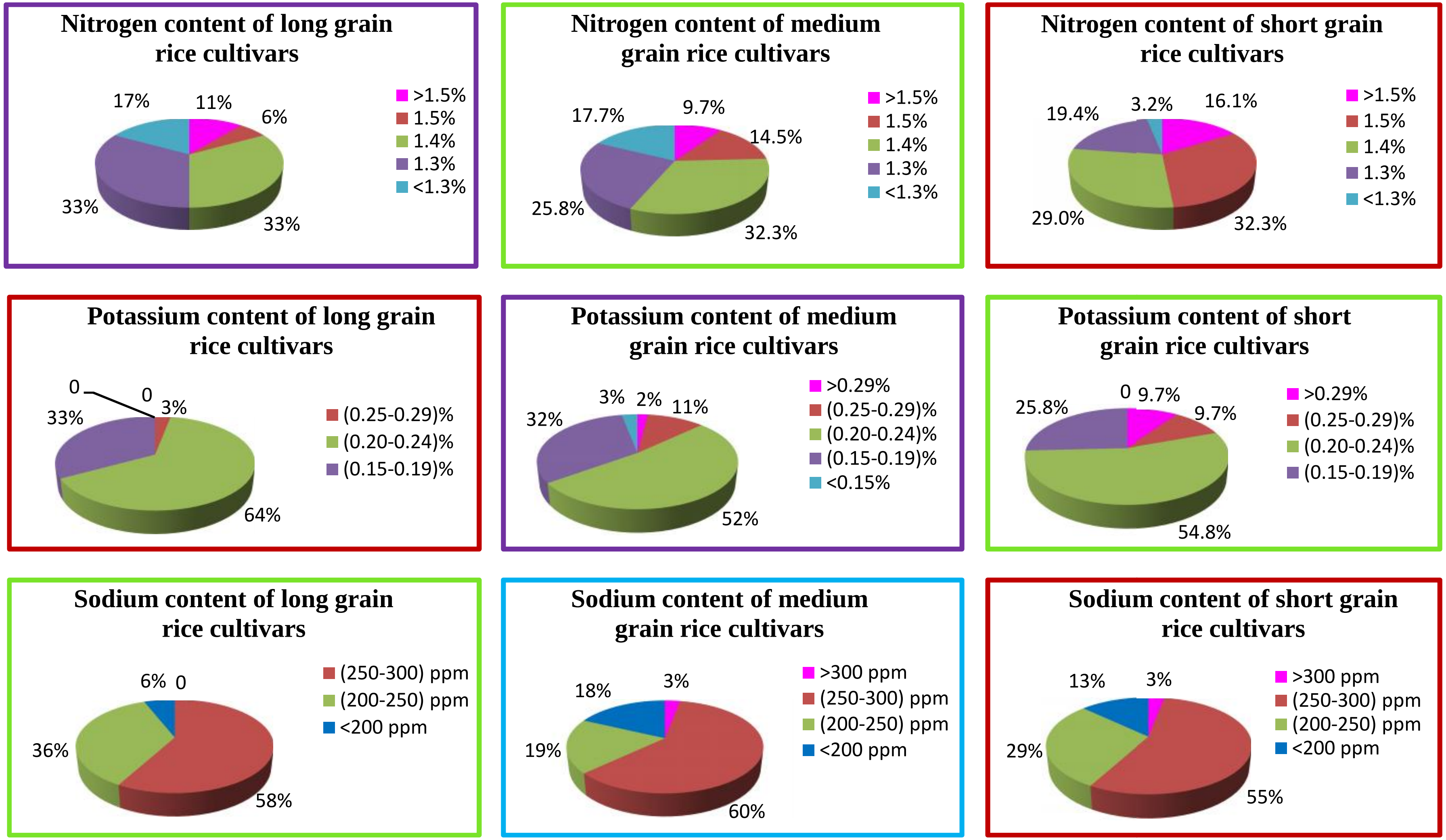

Figure-4.4.2b: Frequency distribution ofnitrogen, potassium and sodium content for long, medium and short grain rice cultivars

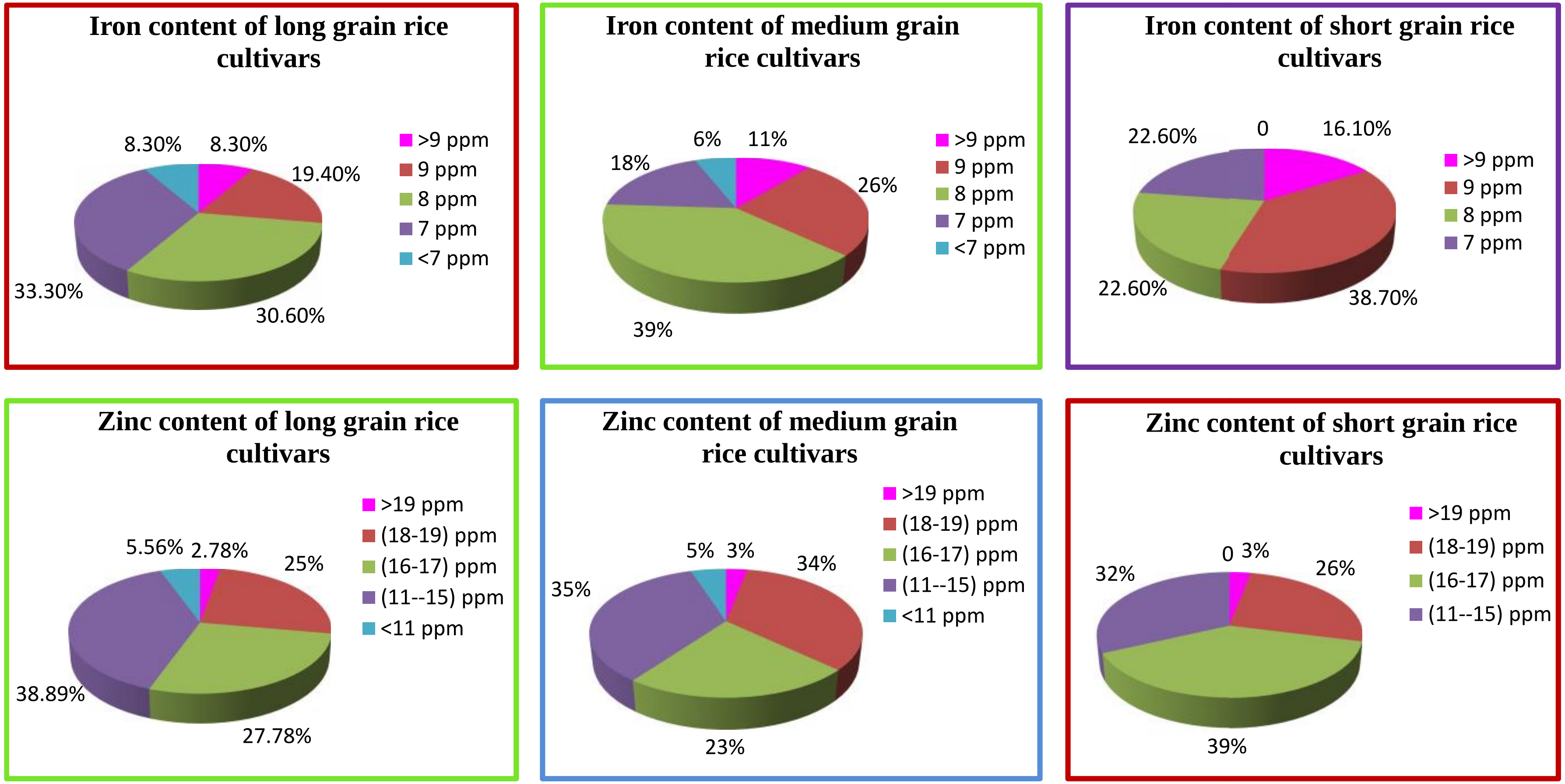

Figure-4.4.2c: Frequency distribution ofiron and zinccontentfor long, medium and short grain rice cultivars

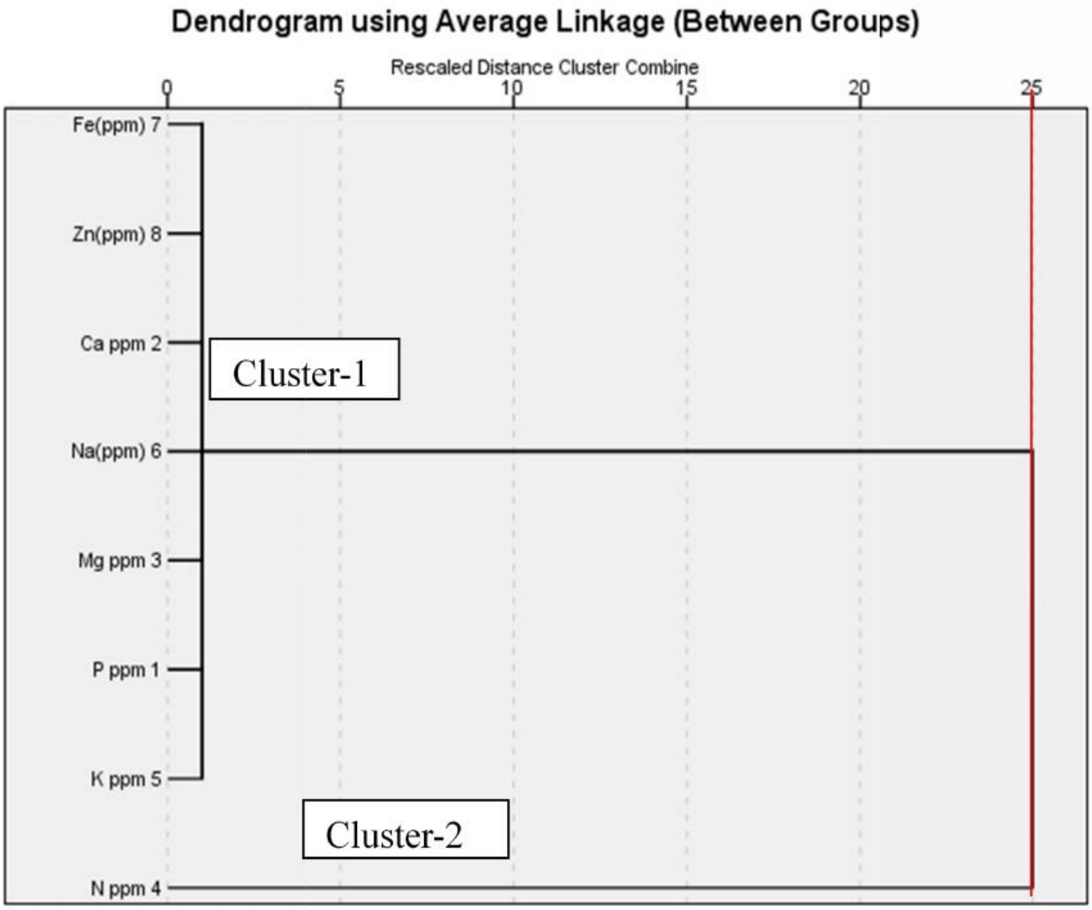

Figure-4.4.3: Dendrogram of mineral elements based on local rice cultivars and HYVs

4.5: Evaluation of nutritional quality for long, medium and short grain rice cultivars

4.5 Nutritional quality

Nutritional quality of rice was determined by its protein and starch digestibility. Content of starch, protein, fractionation of protein, amino acid composition and dietary fiberinfluences the nutritional quality. Among these cultivars, 15 promising cultivars were evaluated for digestibility of protein and starch.

4.5.1 Proximate composition for selected rice cultivars

Proximate composition of 18 selected local rice cultivars was determined. According to the ranking, themean values of carbohydrate, moisture, protein, fat, ash and crude fiber content had 73.4±1.19%, 12.9±0.27%, 8.7±1.24%, 3.0±0.24%, 1.2±0.09% and 0.8±0.09% for selected local rice cultivars. The cultivar of Dudkalam had the highest carbohydrate content (75.07%) and crude fiber content (0.99%). The cultivar of Magoibalam had the highest protein content (10.7%) and Shithabhog had the highest fat content (3.61%). The highest ash content (1.38%) was in Ledabinni but the lowest (1.02%) was in Dudkalam. The cultivars of Kanaibanshi had the highest moisture content (13.4%) but Neda had the lowest (12.3%) moisture content (Table-4.5.1). Pearson correlation coefficients for relationships had among carbohydrate, protein, fat, ash, crude fiber and moisture content of selected local rice cultivars. Protein content was highly significant and negatively correlated with carbohydrate content ($r = -0.936$, $p < 0.01$). Fat content was negatively correlated with carbohydrate and protein content. Ash content was significant and negatively correlated with carbohydrate content ($r = -0.484$, $p < 0.05$) but it was positively correlated with protein and fat content. Crude fiber content was positively correlated with carbohydrate content but negatively correlated with protein and fat content. Crude fiber content also was highly significant and negatively correlated with ash content ($r = -0.682$, $p < 0.01$). Moisture content was positively correlated with carbohydrate, fat and crude fiber content but negatively correlated with protein and ash content (Table-4.5.2).

Clustering of 18 selected local rice cultivars based on carbohydrate, protein, fat, ash, crude fiber and moisture content provided six clusters at level 3.Cluster-1 composed of 5 cultivars; Boradudhkalam, Poushmoricha, Karailadhan, Patnai-231 and Depa comprising cluster-1 was characterized by the range of carbohydrate content (74.30-74.69)%, protein content (7.5-7.9)% and crude fiber content (0.84-0.94)%. Cluster-2 composed of only 1 cultivar; Dudkalam comprising cluster-2 was characterized by the highest quantity of carbohydrate (75.07%) and crude fiber (0.99%) but the lowest quantity of protein (7.0%) and ash (1.02%). Cluster-3 composed of 4 cultivars; Athabinni, Hatisail, Kalabinni-1 and Ledabinni comprising cluster-3 was characterized by the range of carbohydrate content (73.21-73.92)%, protein content (8.2-8.5)% and fat content (3.01-3.31)%.Cluster-4 composed of 3 cultivars; Harilaxmi, Kanaibanshi and Shithabhog comprising cluster-4 was characterized by the range of ash content (1.16-1.29)% and crude fiber content (0.88-0.93)%. Cluster-5 composed of 4 cultivars; Boylam, Magoibalam, Molladigha and Motichak comprising cluster-5 was characterized by the range of carbohydrate content (71.18-71.87)%, protein content (10.2-10.7)% and crude fiber content (0.77-0.84)%. This cluster had the highest range of protein content. Cluster-6 composed of 1 cultivar; Neda comprising cluster-6 was characterized by carbohydrate content (72.59%), protein content (10.5 %), fat content (2.56%) and crude fiber content (0.79%). This clusterhad the lowest quantity of ash and moisture content (Figure-4.5.7).

4.5.2 Protein content for total rice cultivars

Protein content of the studied 129 rice cultivars varied from 6.5% to 10.5% in long grain, 6.5% to 10.7% in medium grain and 7.2% to 9.7% in short grain. Neda had the highest protein content (10.5%) but Dudhkalam had the lowest protein content (7.0%), which was higher than the BR23 (6.5%) in long grain rice cultivars. Magoibalam had the highest protein content (10.7%) but Kumragoir had the lowest protein content (6.5%) in medium grain rice cultivars. Nurior had the highest protein content (9.7%) but Tulsimala had the lowest protein content (7.2%) in short grain rice cultivars. The mean values of long, medium and short grain rice cultivars were 8.15±0.87%, 8.21±0.83% and 8.6±0.64% respectively.

Among the 36 long grain rice cultivars,both Neda and Molladigha had more than 10.0% protein content but Joalbagh, Jol and Harilaxmi had the range of protein content of (9.2-9.8)%. The cultivars of Kalimanik, Athabinni, Kalabinni-1, Gohatibinni, Dudsar Tapal-146, Jingasail-1, Binni-1, Binni-2, Lathamona, Bhorochalam, Shithabhog, Hatisail, BRRI dhan30 and BRRI dhan39 had the range of protein content of (8.0-8.7)%. But, rest of the cultivars had less than 8% protein content. Among the 62 medium grain rice cultivars, Boylam, Magoibalam and Motichak had more than 10.0% protein. The cultivars of Rajamora, Kataribhog-232 and Kalisayta had the range of protein content of (9.4-10)%. Most of the rice cultivars such as Sadamota, Hathazi, Tilokkajal, Pakibiroin, Gobcha, Dadkhani, Kataribhog-2, Bolonga, Putidepa, Chamara, Rangabinni, Somondori, Ledabinni, Changai, Nizersail, Lalmota, Malsira, Maloti, Joyna, Nunia, Kanaklata, Kataribhog-1, Paharisail, Hijli, Kajalsail, Dholagachha and most of the HYVs had the range of protein content of (8.0-8.9)%. But, rest of the cultivars had less than 8% protein content. Among the 31 short grain rice cultivars, Dudsail, Jirakatari-1, Laxmikajal, Rahikhama, Topaboro and BRRI dhan34 had the range of protein content of (9.0-9.6)%. None of the short grain cultivars had more than 10% protein content. Most of the cultivars such as Kalasaru, Pajam, Binniphul, Jirakatari-2, Michisail, Surjyamukhisangla, Sorukamina, Kalijira, Uknimadhu, Khasha, Lalsaru, Baoijhaki, Chinigura, Minki, Chunikanai, Gurdoi, Chinisagor and BR5 had the range of protein content of (8.1-8.9)%. But, rest of the cultivars such as Jabsira, Malagrosa, Murchmut, Betudhan and Nariabochi had the range of (7.3-7.9)% protein content (Table-4.5.3).

More than 9% protein content in rice cultivars is desirable level. Cultivar with 7% protein content is acceptable. Frequency distribution of protein content showed that 14% long, 10% medium and 23% short grain rice cultivars had at the level of >9% protein content. Accordingly, 39% long, 55% medium and 58% short grain rice cultivars had the protein content at the level of (8.0-8.9)% as well as 44% long, 32% medium and 19% short grain rice cultivars had the protein content at the level of (7.0-7.9)%. Only 2% long and 3% medium grain rice cultivars had at the level of <7% protein content (Figure-4.5.1). Local cultivars of both long and medium grain had higher protein content compare to HYVs(Figure-4.5.2). Pearson correlation coefficients for relationships had among protein content of long, medium and short grain rice cultivars. Protein content of long grain rice cultivars was highly significant and positively correlated with protein content of medium grain rice cultivars ($r=1.000$, $p<0.01$). Protein content of short grain rice cultivars was highly significant and negatively correlated with protein content of both long and medium grain rice cultivars ($r= -1.000$, $p<0.01$) (Table-4.5.4).

Cluster analysis of protein content for long, medium and short grain rice cultivars was done through Dendrogram. Among the 32 long grain local rice cultivars, protein content based clustering provided six clusters at level 5. Cluster-1 composed of 7 cultivars; Bhorochalam, Binni-1, Binni-2, Lathamona, Dudsar Tapal-146, Gohatibinni and Jingasail-1 had the range of protein content of (8.3-8.4)%. Cluster-2 composed of 5 cultivars; Kalabinni-1, Athabinni, Hatisail and Shithabhog had the range of protein content of (8.2-8.6)% except Kharmao which had 7.2% protein. It was previous cultivars of Shata. Cluster-3 composed of 9 cultivars; Shata, Dudhkalam, Depa, T.R.Aman, Khorma, Boradudhkalam, Kanaibansi, Patnai-231 and Tk deep straw Tapl-773 had the range of protein content of (7.0-7.6)%. Cluster-4 composed of 6 cultivars; Redpiebald-219, Karailadhan, Kalimanik, Sadajira Tapl-321, Pakhisail and Cylindrical Tapi-629 had the range of protein content of (7.7-7.9)%. Cluster-5 composed of 2 cultivars; Molladigha and Neda had the range of protein content of (10.3-10.5)%. Cluster-6 composed of 3 cultivars; Joalbagh, Jol and Harilaxmi had the range of (9.2-9.8)%protein content (Figure-4.5.8a).

Among the 48 medium grain local rice cultivars, protein content based clustering provided eight clusters at level 5. Cluster-1 composed of 9 cultivars; Nunia, Kanaklata, Malsira, Maloti, Joyna, Kajalsail, Dholagachha, Gojalgoria and Bariksail had the range of protein content of (7.9-8.2)%. Cluster-2 composed of 11 cultivars; Kataribhog-1,Paharisail, Hijli, Chamara, Somondori,Changai, Ledabinni, Putidepa, Rangabinni,Nizersail and Lalmota had the range of protein content of (8.0-8.5)%. Cluster-3 composed of 7 cultivars; Rajamora, Sadamota, Kataribhog-232, Hathazi, Dadkhani, Kataribhog-2 and Tilokkajal had the range of protein content of (8.8-9.5)%. Cluster-4 composed of 3 cultivars; Pakibiroin, Gobcha and Bolonga had the range of protein content of (8.7-8.8)%. Cluster-5 composed of 6 cultivars; Hashfol, Tilkapur, Jhoshua, Lohasail, Lalbinni and Ganjia had the range of protein content of(7.0-7.4)%. Cluster-6 composed of 7 cultivars; Jhingasail-2, Shamrosh, Lalsoru, Najirsail,Kalabinni-2 and Nakchi had the range of protein content of (7.5-7.8)%. Cluster-7 composed of 1 cultivar; Kumragoir had the lowest protein content (6.5%). Cluster-8 composed of 4 cultivars; Boylam, Kalisayta, Magoibalam and Motichak had the range of (10.0-10.7)% highest protein content (Figure-4.5.8b).

Among the 29 short grain local rice cultivars, protein content based clustering provided six clusters at level 3. Cluster-1 composed of 2 cultivars; both Kalasaru and Pajam had 8.9% protein content. Cluster-2 composed of 8 cultivars; Binniphul, Khasha, Lalsaru, Laxmikajol, Baoijhaki, Dudsail, Chinigura and Jirakatari-2 had the range of protein content of (8.4-9.0)%. Cluster-3 composed of 5 cultivars; Kalijira, Surjyamukhisangla, Sorukamina, Uknimadhu and Michisail had the range of protein content of (8.5-8.7)%. Cluster-4 composed of 7 cultivars; Jabsira, Malagrosa, Chinisagor, Chunikanai, Gurdoi, Murchmut and Minki had the range of protein content of (7.8-8.3)%. Cluster-5 composed of 4 cultivars; Rahikhama, Nurior, Topaboro and Jirakatari-1 had the range of protein content of (9.4-9.7)%. Cluster-6 composed of 3 cultivars; Nariabochi, Betudhan and Tulsimala had the range of (7.2-7.5)% protein content (Figure-4.5.8c).

4.5.3 Effect of processing on protein content for selected rice cultivars

4.5.3.1 Milling effect: Protein content in rice indicates only the dietary protein. Brown rice of cultivars had the range of protein content of (7.0-10.7)% with the mean value of 8.6±1.36%. Brown rice of Magoibalam had the highest protein content (10.7%) but Dudhkalam had the lowest protein content (7.0%). Milling was found to reduce protein content of the cultivars. Milled rice of these cultivars retained protein content range of (6.2-9.6)% with the mean value of 7.7±1.34%.Milled rice of Neda had the highest protein content (9.6%) but Dudhkalam had the lowest protein content (6.2%). Protein loss due to milling varied from 8.6% to 14.5% with the mean value of 11.6±1.9%. Here, milled rice of Depa had the highest protein loss (14.5%) with lower milled rice protein (6.5%) and Boradudhkalam had higher protein loss (13.3%) with lower milled rice protein (6.5%) but Neda had the lowest protein loss (8.6%) with highest milled rice protein (9.6%) and Boylam had lower protein loss (8.8%) with higher milled rice protein (9.3%) after milling among the 15 selected local rice cultivars. So, Cultivars with higher brown rice protein had a lower milling loss of protein (Table-4.5.5).

4.5.3.2 Cooking effect: Similarly, protein is also lost in cooking. Cooking in excess water, Neda retained the highest cooked rice protein (8.83%) but Kanaibansi retained the lowest cooked rice protein (5.74%) with the mean value of 6.86±1.26%. Cooking in excess water, the highest protein loss due to cooking resulted in Ledabinni (20%) whereas the lowest protein loss due to cooking resulted in Dudhkalam and Karailadhan (4%) with the mean value of 10.52±4.59%. Kalabinni-1 had the second highest protein loss due to cooking (17.8%). Cultivars of Kanaibansi, Magoibalam, Poushmoricha and Boradudhkalam had the range of protein loss due to cooking of (10.0-11.7)% in cooked rice. Other cultivars such as Depa, Molladigha, Patnai-231, Neda and Boylam had the range of protein loss due to cooking of (7.0-8.6)% in cooked rice (Table-4.5.5).

Pearson correlation coefficients for relationships had among the protein content of brown, milled and cooked rice as well as protein loss of milled and cooked rice for 15 selected local rice cultivars. Milled rice protein was highly significant and positively correlated with brown rice protein ($r=0.997$, $p<0.01$). Milling loss of protein was highly significant and negatively correlated with both brown rice protein as well as milled rice protein ($r= -0.757$, -0.806, $p<0.01$). Cooked rice protein was highly significant and positively correlated with brown rice protein as well as milled rice protein (r=0.956, 0.963, p<0.01). But it was highly significant and negatively correlated with protein loss of milled rice (r= -0.800, p<0.01). Protein loss of cooked rice was positively correlated with brown rice protein, milled rice protein and milled rice protein loss but negatively correlated with cooked rice protein (Table-4.5.6). Brown rice showed the highest protein content followed by milled rice and then cooked rice among the selected local rice cultivars (Figure-4.5.3). Milled rice had higher protein loss than that of cooked rice among the 15 selected local rice cultivars (Figure-4.5.4).

Protein content of brown, milled and cooked rice as well as loss of protein for milled and cooked rice for 15 selected local rice cultivars based clustering provided 5 clusters: three clusters (cluster-1, cluster-2 and cluster-3) at level below 4.5 and two clusters at level above 4.5 (mentioned in protein digestibility). Cluster-1 composed of 7 cultivars; Boradudhkalam, Boylam, Depa, Kanaibanshi, Molladigha, Neda and Pousmoricha comprising cluster-1 was characterized by protein loss due to milling. Among them, Boylam, Molladigha and Neda had low protein loss due to milling having the range of (8.6-9.7)%. But, rest of the cultivars such as Depa,Boradudhkalam, Kanaibanshi and Pousmoricha had high protein loss due to milling having the range of (13.3-14.5)%. Cluster-2 composed of 1 cultivar; Patnai-231 comprising cluster-2 was characterized by protein loss due to milling having the value of 12%, which was different from the above cultivars. Cluster-3 composed of 5 cultivars; Dudhkalam, Karailadhan, Athabinni, Ledabinni and Kalabinn-1 comprising cluster-3 was characterized by brown and cooked rice protein. These cultivars had the range of (7.0-8.4)% of brown rice and (5.95-6.72)% of cooked rice protein (Figure-4.5.9).

4.5.4 Fractionation ofprotein for selected rice cultivars

Rice proteins were classified by their solubility such as albumin (soluble in pure water), globulin (soluble in salt-water), prolamin (soluble in alcohol) and glutelin (soluble in aqueous alkaline solution) (Hoseney, 1986). Tenrice cultivarswere selectedforfractionation ofprotein. Among these cultivars, albumin varied from 7.3 g/100g to 12.2 g/100gwith the mean value of 9.9±1.52 g/100g.Magoibalam had the highest albumin followed by Motichak and Boylam,whereasDudhkalam had the lowest albumin. Cultivars such as Jol, Karailadhan, Neda, Athabinni, Molladigha and BRRI dhan28 had the range of albumin of (8.3-10.9) g/100g. Among these cultivars, globulin varied from 4.6 g/100g to 6.7 g/100gwith the mean value of 5.4±0.73 g/100g.Athabinni had the highest globulin followed by Dudkalam and Boylam,whereasboth Molladigha and Karailadhan had the lowestglobulin. Cultivars such asMotichak, Neda, Jol, Magoibalam and BRRI dhan28 had the range of globulin of (8.3-10.9) g/100g. Among these cultivars, prolamin varied from 4.0 g/100g to 4.9 g/100gwith the mean value of 4.5±0.31 g/100g.Dudkalam had the highest prolamin followed by Athabinni, Magoibalam and Motichakwhich had the similar value, whereasNeda had the lowestprolamin.Cultivars such as Jol, Karailadhan,Boylam, Molladigha and BRRI dhan28 had the range of prolamin of (4.1-4.6) g/100g. Among these cultivars, glutelin varied from 78.0 g/100g to 82.8 g/100gwith the mean value of 80.1±1.58 g/100g. Molladigha had the highest glutelin followed by Karailadhan and Dudkalam, whereas Magoibalam had the lowestglutelin. Cultivars such as Jol,Neda, Athabinni, Motichak, Boylam and BRRI dhan28had the range of glutelin of (78.4-80.7) g/100g (Table-4.5.7).

Pearson correlation coefficients for relationships had among albumin, globulin, prolaminglutelin and protein content of 10 selected rice cultivars. Albumin was significant and positively correlated with protein content ($r=0.744$, $p<0.05$) whereas,globulin, prolaminand glutelin were negatively correlated with protein content. Albumin was highly significant and negatively correlated with glutelin ($r=0.858$, $p<0.01$) as well as albumin was only negatively correlated with globulin and prolamin (Table-4.5.8). Among the rice cultivars, glutelin showed the highest amount of fractionation ofprotein followed by albumin then globulin and prolamin (Figure-4.5.5). Fractionation of protein (albumin, globulin, prolamin and glutelin) for selected rice cultivars based clustering provided six clusters at level 5. Cluster-1 composed of 2 cultivars; Boylam and Motichak comprising cluster-1 was characterized by almost similar albumin content (11.2 and 11.3) g/100g as well as similar glutelin content (78.7 and 78.4) g/100g. Cluster-2 composed of 3 cultivars; Magoibalam, BRRI dhan28 and Neda comprising cluster-2 was characterized by glutelin having the range of (78.0-80.7) g/100g. Cluster-3 composed of 1 cultivar; Jol comprising cluster-3 was characterized by lower globulin having the value of 4.7 g/100g. Cluster-4 composed of 1 cultivar; Athabinni comprising cluster-4 was characterized by highest globulin having the value of 6.7 g/100g. Cluster-5 composed of 2 cultivars; Molladigha and Kariladhan comprising cluster-5 was characterized by the lowest globulin (4.6 g/100g) as well as highest glutelin having the range of (81.8-82.8) g/100g. Cluster-6 composed of 1 cultivar; Dudhkalam comprising cluster-6 was characterized by lowest albumin (7.3 g/100g) and highest prolamin (4.9 g/100g) (Figure-4.5.10).

4.5.5 Amino acid composition for selected rice cultivars

Seventeen different essential and non-essential amino acids were separated on a high performance anion-exchange column and directly detected them. Nine rice cultivarswere selectedforamino acid composition. Arginine varied from 7.76 g/100g to 10.49 g/100gwith the mean value of 9.64±1.17g/100g; Motichak had the highest arginine but Athabinni had the lowest arginine. Lysinevaried from 3.34 g/100g to 4.29 g/100gwith the mean value of 3.87±0.38g/100g; Magoibalam had the highest lysine but Karailadhan had the lowest lysine. Alaninevaried from 5.24 g/100g to 5.79 g/100gwith the mean value of 5.55±0.21g/100g; Motichak had the highest alanine but Neda had the lowest alanine.Threoninevaried from 3.34 g/100g to 3.97 g/100gwith the mean value of 3.71±0.24g/100g; Magoibalam had the highest threonine but Molladigha had the lowest threonine. Glycinevaried from 4.51 g/100g to 4.80 g/100gwith the mean value of 4.64±0.11g/100g; Neda had the highest glycine but Jol had the lowest glycine. Valinevaried from 5.10 g/100g to 7.25 g/100gwith the mean value of 6.25±1.08g/100g; Jol had the highest valine but Karailadhan had the lowest valine. Serinevaried from 4.69 g/100g to 5.74g/100gwith the mean value of 5.31±0.41g/100g; Molladigha had the highest serine but Athabinni had the lowest serine.

Proline was found in Magoibalamand Molladigha; isoleucine was found only in BRRIdhan28 as well as leucine was found in BRRIdhan28 and Neda among the selected rice cultivars.Methioninevaried from 2.09 g/100g to 2.23 g/100gwith the mean value of 2.17±0.07g/100g; Karailadhan had the highest methionine but Molladigha had the lowest methionine. Histidinevaried from 2.23 g/100g to 2.61 g/100gwith the mean value of 2.45±0.14g/100g; BRRI dhan28 had the highest histidine but Motichak had the lowest histidine. Phenylalanine varied from 4.93 g/100g to 5.32 g/100gwith the mean value of 5.11±0.15g/100g; Boylam had the highest phenylalanine but Molladigha had the lowest phenylalanine. Glutamate varied from 17.39 g/100g to 18.30 g/100gwith the mean value of 17.94±0.38g/100g; Athabinni had the highest glutamate but Jol had the lowest glutamate. Aspartate varied from 8.74 g/100g to 9.50 g/100gwith the mean value of 9.16±0.33g/100g; Motichak had the highest aspartate but Jol had the lowest aspartate. Cystine varied from 1.36 g/100g to 2.40 g/100gwith the mean value of 2.12±0.33 g/100g; Boylam had the highest cystine but BRRI dhan28 had the lowest cystine. Tyrosine varied from 4.44 g/100g to 5.83 g/100gwith the mean value of 5.39±0.47g/100g; Magoibalamhad the highest tyrosine but Athabinni had the lowest tyrosine (Table-4.5.9).

Pearson correlation coefficients for relationships had among the 17 amino acids with protein content of 9 selected rice cultivars.Lysine was highly significant and positively correlated with aspartate (r=0.921, p<0.01) whereas,lysine was significant and negatively correlated with valine (r= -0.733, p<0.05). Lysine waspositively correlated withargenin, threonine, glycine, proline, histidine, phenylalanine, glutamate and cystine whereas lysine was negatively correlated with alanine, serine, isoleucine, leucine, methionine and tyrosine. Protein was highly significant and positively correlated withlysine (r=0.882, p<0.01) as well as aspartate (r=0.835, p<0.01). It was positively correlated withargenin, threonine, glycine, proline, histidine, phenylalanine, glutamate and cystine, whereas it wasnegatively correlated with alanine, valine, serine, isoleucine, leucine, methionine and tyrosine(Table-4.5.10). Among the rice cultivars, glutamate showed the highest amount of amino acid composition followed by arginine (Figure-4.5.5). Different amino acid peaks of selected rice cultivars had shown in chromatograms (Figure-4.5.6a, Figure-4.5.6b and Figure-4.5.6c). Amino acid composition (arginine, lysine, alanine, threonine, glycine, valine, serine, proline,isoleucine, leucine, methionine, histidine, phenylalanine, glutamate, aspartate, cystine and tyrosine) for selected rice cultivarsbased clustering provided five clusters at level 15. Cluster-1 composed of 2 cultivars; Athabinni and Jol comprising cluster-1 was characterized by almost similar glycine (4.57 and 4.51) g/100g as well as histidine (2.47 and 2.48) g/100g.Cluster-2 composed of 1 cultivar; Kariladhan comprising cluster-2 was characterized by lowest lysine (3.34 g/100g)and lowest valine (5.10 g/100g).Cluster-3 composed of 2 cultivars; Boylam and Motichak comprising cluster-3 was characterized by the highest ranges of arginine, alanine and aspartate having the ranges of (10.47-10.49) g/100g, (5.75-5.79) g/100g and (9.49-9.50) g/100g.Cluster-4 composed of 2 cultivars; Magoibalam and Molladigha comprising cluster-4 was characterized by all most similar glutamate having the values of (18.16 and 18.14) g/100g, highest values of threonine and proline (3.97 and 5.11) g/100g as well as lowest values of threonine and proline (3.34 and 4.73) g/100g.Cluster-5 composed of 2 cultivars; Neda and BRRI dhan28 comprising cluster-5 was characterized by almost similar glutamate having the values of (17.45and 17.48) g/100g, the lowest range of alanine (5.24-5.27) g/100g and the lowest range of cystine (1.36-1.97) g/100g (Figure-4.5.11).

4.5.6 Protein digestibilityfor selected rice cultivars

Nutritional value of protein depends on its digestibility. Selected 15 local rice cultivars were analyzed for protein digestibility of milled rice. Protein digestibility of local rice cultivars varied from 59% to 78%. Magoibalam had the highest protein digestibility (78%). The higher protein digestibility had it's the higher nutritional value. Several factors such as amino acid composition of protein (Eppendorfer *et al.*, 1983), fat, fiber, phytate, trypsin and tannin may influence the protein digestibility substantially (Gilani *et al*., 2005). It was observed that cultivars with higher protein content had higher protein digestibility except Kalabinni-1 which had the higher protein digestibility (68%) with intermediate protein content (8.2%). High protein content rice cultivars of Magoibalam, Motichak, Neda, Molladigha and Boylam had the protein digestibility of 78%, 72%, 68%, 67% and 67% respectively (Table-4.5.5).

Pearson correlation coefficients for relationships had among the protein digestibility, protein content of brown, milled and cooked rice as well as protein loss of milled and cooked rice for15 selected local rice cultivars.Brown rice protein was highly significant and positively correlated with protein digestibility ($r=0.757$, $p<0.01$). Milled rice protein was highly significant and positively correlated with protein digestibility ($r=0.755$, $p<0.01$). Protein loss of milled rice was significant and negatively correlated with protein digestibility ($r= -0.610$, $p<0.05$).Cooked rice protein was highly significant and positively correlated with protein digestibility, ($r=0.694$, $p<0.01$). Protein loss of cooked rice was positively correlated with protein digestibility (Table-4.5.6). Protein digestibility of 15 selected local rice cultivars based clustering provided 5 clusters: three clusters at level below 4.5 (mentioned earlier) and two clusters (cluster-4 and cluster-5) at level above 4.5. Cluster-4 composed of 1 cultivar; Magoibalam comprising cluster-4 was characterized by the highest protein digestibility (78%),protein loss due to milling (11.2%)andprotein loss due to cooking (11.1%).Cluster-5 composed of 1 cultivar; Motichak comprising cluster-5 was characterized by the second highest protein digestibility (72%), protein loss due to milling (9.5%) and protein loss due to coking (12.9%). Cultivars of both Magoibalam and Motichak had the same (9.5%) milled rice protein (Figure-4.5.9).

4.5.7 Starch digestibilityfor selected rice cultivars

Amylose content of starch influences the starch digestibility. Starch digestibility of selected 15 local rice cultivars varied from 51.57% to 68.92% at 20 minutes digestion. Athabinni of low amylose had the highest starch digestibility (68.92%) but Poushmoricha of high amylose had the lowest starch digestibility (51.57%). Low and intermediate amylose cultivars had higher starch digestibility than those of high amylose rice cultivars at 20 minutes digestion. After 20 minutes of digestion, the digestibility of the tested rice cultivars increased. Low amylose rice cultivars had higher starch digestibility than those of intermediate and high amylose rice cultivars at 120 minutes digestion. At 120 minutes digestion, digestibility rate was found slowly in all the rice cultivars. It varied from 62.31%

to 83.79%. Athabinni of low amylose had the highest starch digestibility (83.79%) but Dudkalam of high amylose had the lowest starch digestibility (62.31%) at 120 minutes digestion. Starch digestibility of standard (rice starch) as check had 73.87% digestibility at 20 minutes and 90.4% at 120 minutes (Table-4.5.11).

Pearson correlation coefficients for relationships had among starch digestibility of 15 selected local rice cultivars at 0 minute, 20 minutes and 120 minutes. Starch digestibility of selected local rice cultivars at 20 minutes was highly significant and positively correlated with starch digestibility of same cultivars at 0 minute ($r=0.806$, $p<0.01$). Starch digestibility of selected local rice cultivars at 120 minutes was negatively correlated with starch digestibility of same cultivars at 0 minute and 20 minutes (Table-4.5.12).

Starch digestibility of the 15 selected local rice cultivars based clustering provided six clusters at level 3. Cluster-1 composed of 6 cultivars; Depa, Molladigha, Karailadhan, Patnai-231, Boradudkalam and Dudkalam comprising cluster-1 was characterized by starch digestibility (4.48%) at 0 minute among the cultivars of high amylose content. Cluster-2 composed of 1 cultivar; Poushmoricha comprising cluster-2 was characterized by the lowest starch digestibility (51.57%) at 20 minutes among the cultivars of high amylose content. Cluster-3 composed of 4 cultivars; Neda, Kalabinni-1, Kanaibanshi and Ledabinni comprisingcluster-3 was characterized by the ranges of starch digestibility of **(**6.13-6.96)%, (65.12-66.31)% and (78.83-83.46)% at 0 minute, 20 minutes and 120 minutesrespectively, among the cultivars for intermediate and low amylose content. Cluster-4 composed of 1 cultivar; Athabinni comprising cluster-4 was characterized by the highest starch digestibility (7.78%, 68.92% and 83.79%) at 0, 20 and 120 minutes respectively, among the cultivars of low amylose content. Cluster-5 composed of 3 cultivars; Boylam, Motichak and Magoibalam comprising cluster-5 was characterized by the range of starch digestibility (4.81-5.80)%, (60.66-64.79)% and (70.57-75.53)% at 0, 20 and 120 minutes respectively, among the cultivars for high amylose content. Cluster-6 composed of 1 standard starch; rice starch comprising cluster-6 was characterized by starch digestibility of 14.39%, 73.87% and 90.4% at 0 minute, 20 minutes and 120 minutesrespectively (Figure-4.5.12).

Table-4.5.1: Mean performance of proximate composition forselected local rice cultivars

Sl. No.	Cultivars	Carbohydrate (%)	Protein (%)	Fat (%)	Ash (%)	Crude fiber (%)	Moisture (%)
1	Athabinni	73.92±0.51	8.2±0.78	3.31±0.02	1.37±0.01	0.80±0.08	12.4±0.67
2	Boradudhkalam	74.69±0.31	7.5±0.38	2.77±0.04	1.20±0.03	0.94±0.09	12.9±0.62
3	Boylam	71.87±0.53	10.2±0.15	3.03±0.01	1.30±0.03	0.80±0.09	12.8±0.65
4	Depa	74.47±0.80	7.6±0.15	2.85±0.03	1.19±0.02	0.89±0.08	13.0±0.61
5	Dudhkalam	75.07±0.74	7.0±0.26	2.92±0.03	1.02±0.01	0.99±0.11	13.0±0.59
6	Harilaxmi	73.27±0.25	9.2±0.06	2.88±0.05	1.16±0.02	0.89±0.12	12.6±0.49
7	Hatisail	73.21±0.75	8.5±0.45	3.11±0.05	1.23±0.02	0.75±0.09	13.2±0.50
8	Kalabinni-1	73.70±1.06	8.2±0.10	3.01±0.03	1.25±0.02	0.74±0.12	13.1±0.93
9	Kanaibanshi	73.59±1.10	7.5±0.39	3.34±0.02	1.29±0.03	0.88±0.10	13.4±0.46
10	Karailadhan	74.30±0.57	7.9±0.46	2.79±0.04	1.17±0.03	0.84±0.05	13.0±0.51
11	Ledabinni	73.76±0.51	8.4±0.39	3.15±0.04	1.38±0.01	0.61±0.08	12.7±0.67
12	Magoibalam	71.18±1.16	10.7±0.06	3.17±0.05	1.31±0.02	0.84±0.09	12.8±0.56
13	Molladigha	71.52±1.66	10.3±0.15	3.03±0.03	1.27±0.02	0.78±0.07	13.1±0.35
14	Motichak	71.78±0.95	10.5±0.06	2.93±0.04	1.32±0.02	0.77±0.08	12.7±0.90
15	Neda	72.59±1.08	10.5±0.25	2.56±0.02	1.26±0.03	0.79±0.10	12.3±0.46
16	Patnai-231	74.49±1.15	7.5±0.15	3.02±0.03	1.32±0.02	0.87±0.12	12.8±0.76
17	Poushmoricha	74.53±0.49	7.7±0.66	2.98±0.02	1.15±0.03	0.94±0.06	12.7±0.78
18	Shithabhog	72.60±0.98	8.6±0.25	3.61±0.03	1.26±0.02	0.93±0.07	13.0±0.67
Range		**71.18-75.07**	**7.0-10.7**	**2.56-3.61**	**1.02-1.38**	**0.61-0.99**	**12.3-13.4**
Mean±SD		**73.4±1.19**	**8.7±1.24**	**3.0±0.24**	**1.2±0.09**	**0.8±0.09**	**12.9±0.27**
CV%		**2**	**14**	**8**	**7**	**11**	**2**
SE (Standard error)		**0.201**	**0.835-01**	**0.829**	**0.504-02**	**0.184**	**0.131**
LSD (0.05)		**0.580**	**0.240**	**0.238-01**	**0.145-01**	**0.528-01**	**0.377**

Table-4.5.2: The Pearson correlation coefficient of proximate compositionforselectedlocal rice cultivars

Correlations

Parameters	**Carbohydrate (%)**	**Protein (%)**	**Fat (%)**	**Ash (%)**	**Crude fiber (%)**
Carbohydrate (%)	1				
Protein (%)	-.936**	1			
Fat (%)	-.203	-.096	1		
Ash (%)	-.484*	.416	.411	1	
Crudefiber (%)	.386	-.421	-.036	-.682**	1
Moisture (%)	.097	-.370	.319	-.235	.148

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table-4.5.3: Mean performance of protein content for long, medium and short grain rice cultivars

Long grain			Medium grain						Short grain		
SL.No.	**Cultivars**	**Protein (%)**	**SL.No.**	**Cultivars**	**Protein (%)**	**SL.No.**	**Cultivars**	**Protein (%)**	**SL.No.**	**Cultivars**	**Protein (%)**
1	Athabinni	8.2±0.78	1	Bariksail	7.9±0.73	37	Nunia	8.1±0.22	1	Baoijhaki	8.4±0.33
2	Bhorochalam	8.4±0.14	2	Bolonga	8.7±0.27	38	Paharisail	8.0±0.15	2	Betudhan	7.5±0.34
3	Binni-1	8.4±0.90	3	Boylam	10.2±0.15	39	Pakibiroin	8.8±0.44	3	Binniphul	8.8±0.60
4	Binni-2	8.4±0.65	4	Chamara	8.5±0.54	40	Poushmoricha	7.7±0.66	4	Chinisagor	8.1±0.13
5	Boradudhkalam	7.5±0.38	5	Changai	8.4±0.20	41	Putidepa	8.5±0.35	5	Chinigura	8.4±0.34
6	Cylindrical Tapi-629	7.8±0.50	6	Dadkhani	8.8±0.16	42	Rajamora	9.4±0.30	6	Chunikanai	8.2±0.84
7	Depa	7.6±0.15	7	Dholagachha	8.0±0.39	43	Rangabinni	8.5±0.39	7	Dudsail	9.0±0.30
8	Dudhkalam	7.0±0.26	8	Ganjia	7.3±0.34	44	Sadamota	8.9±0.44	8	Gurdoi	8.2±0.60
9	Dudsar Tapal-146	8.3±0.67	9	Gobcha	8.8±0.24	45	Shamrosh	7.5±0.56	9	Jabsira	7.9±0.57
10	Gohatibinni	8.3±0.25	10	Gojalgoria	7.9±0.15	46	Somondori	8.4±0.20	10	Jirakatari-1	9.4±0.27
11	Harilaxmi	9.2±0.06	11	Hashfol	7.0±0.25	47	Tilkapur	7.0±0.17	11	Jirakatari-2	8.8±0.43
12	Hatisail	8.5±0.45	12	Hathazi	8.9±0.26	48	Tilokkajal	8.8±0.27	12	Kalasaru	8.9±0.15
13	Jingasail-1	8.3±0.50	13	Hijli	8.0±0.25	49	BR4	7.7±0.30	13	Kalijira	8.6±0.30
14	Joalbagh	9.8±0.13	14	Jhingasail-2	7.8±0.17	50	BR10	7.6±0.10	14	Khasha	8.5±0.89
15	Jol	9.6±0.25	15	Jhoshua	7.1±0.36	51	BR11	7.5±0.33	15	Lalsaru	8.5±0.40
16	Kalabinni-1	8.2±0.10	16	Joyna	8.2±0.52	52	BR22	7.4±0.34	16	Laxmikajol	9.0±0.25
17	Kalimanik	8.0±0.10	17	Kajalsail	8.0±0.34	53	BR25	8.5±0.15	17	Malagrosa	7.9±0.25
18	Kanaibansi	7.5±0.39	18	Kalabinni -2	7.6±0.67	54	BRRI dhan31	8.4±0.12	18	Michisail	8.7±0.25
19	Karailadhan	7.9±0.46	19	Kalisayta	10.0±0.15	55	BRRI dhan32	8.2±0.20	19	Minki	8.3±0.26
20	Kharmao	7.2±0.58	20	Kanaklata	8.1±0.48	56	BRRI dhan33	8.5±0.35	20	Murchmut	7.8±0.44
21	Khorma	7.6±0.38	21	Kataribhog-1	8.0±0.45	57	BRRI dhan37	8.8±0.43	21	Nariabochi	7.3±0.35
22	Lathamona	8.4±0.33	22	Kataribhog-2	8.8±0.13	58	BRRI dhan38	8.2±0.83	22	Nurior	9.7±0.10
23	Molladigha	10.3±0.15	23	Kataribhog-232	9.5±0.15	59	BRRI dhan40	8.3±0.46	23	Pajam	8.9±0.45
24	Neda	10.5±0.25	24	Kumragoir	6.5±0.40	60	BRRI dhan44	8.2±0.40	24	Rahikhama	9.6±0.33
25	Pakhisail	7.7±0.24	25	Lalbinni	7.4±0.45	61	BRRI dhan46	6.9±0.15	25	Sorukamina	8.6±0.34
26	Patnai-231	7.5±0.15	26	Lalmota	8.3±0.35	62	BRRI dhan49	7.6±0.44	26	Surjyamukhisangla	8.7±0.15
27	Redpiebald-219	7.9±0.51	27	Lalsoru	7.5±0.45				27	Topaboro	9.6±0.24
28	Sadajira tapl-321	7.7±0.18	28	Ledabinni	8.4±0.39				28	Tulsimala	7.2±0.59
29	Shata	7.2±0.23	29	Lohasail	7.4±0.49				29	Uknimadhu	8.5±0.72
30	Shithabhog	8.6±0.25	30	Magoibalam	10.7±0.06				30	BR5	8.8±0.10
31	T.R.Aman	7.6±0.77	31	Maloti	8.2±0.34				31	BRRI dhan34	9.4±0.20
32	TK deep straw Tapl-773	7.4±0.46	32	Malsira	8.2±0.77						
33	BR23	6.5±0.05	33	Motichak	10.5±0.06						
34	BRRI dhan30	8.2±0.25	34	Najirsail	7.6±0.29						
35	BRRI dhan39	8.7±0.56	35	Nakchi	7.6±0.35						
36	BRRI dhan41	7.6±0.51	36	Nizersail	8.3±0.40						
Range		**6.5-10.5**	**Range**		**6.5-10.7**				**Range**		**7.2-9.7**
Mean±SD		**8.15±0.87**	**Mean±SD**		**8.21±0.83**				**Mean±SD**		**8.6±0.64**
CV%		**11**	**CV%**		**10**				**CV%**		**8**
SE(Standard error)		**0.707-01**	**SE(Standard error)**		**0.473-01**				**SE(Standard error)**		**0.664-01**
LSD (0.05)		**0.1995**	**LSD(0.05)**		**0.132**				**LSD(0.05)**		**0.189**

Table-4.5.4:The Pearson correlation coefficient for different rice cultivarson the basis of protein content

Correlations		
Cultivars (Protein content %)	**Long grain rice cultivars**	**Medium grain rice cultivars**
Long grain rice cultivars	1	
Medium grain rice cultivars	1.000**	1
Short grain rice cultivars	-1.000**	-1.000**

**Correlation is significant at the 0.01 level (2-tailed).

Table-4.5.5: Effect of milling and cooking on protein content and in vitro protein digestibility for selected local rice cultivars

Sl.No.	Cultivars	Protein (%)					
		Brown rice	Milled rice	Cooked rice	Protein loss due to milling	Protein loss due to cooking	Protein digestibility
1	Athabinni	8.2±0.78	7.1±0.10	5.98±0.16	13.4±0.65	15.8±0.35	63±2.52
2	Boradudhkalam	7.5±0.38	6.5±0.14	5.85±0.07	13.3±0.28	10.0±0.43	64±3.61
3	Boylam	10.2±0.15	9.3±0.12	8.65±0.09	8.8±0.37	7.0±0.39	67±4.36
4	Depa	7.6±0.15	6.5±0.42	5.94±0.13	14.5±0.39	8.6±0.33	59±1.53
5	Dudhkalam	7.0±0.26	6.2±0.15	5.95±0.13	11.4±0.25	4.0±0.30	66±4.16
6	Kalabinni-1	8.2±0.10	7.3±0.16	6.00±0.04	11.0±0.29	17.8±0.25	68±4.16
7	Kanaibansi	7.5±0.39	6.5±0.24	5.74±0.06	13.3±0.40	11.7±0.32	62±3.79
8	Karailadhan	7.9±0.46	7.0±0.17	6.72±0.04	11.4±0.33	4.0±0.44	61±2.65
9	Ledabinni	8.4±0.39	7.5±0.21	6.00±0.02	10.7±0.20	20.0±0.28	63±2.00
10	Magoibalam	10.7±0.06	9.5±0.20	8.45±0.11	11.2±0.29	11.1±0.40	78±4.93
11	Molladigha	10.3±0.15	9.3±0.27	8.52±0.16	9.7±0.45	8.4±0.30	67±4.16
12	Motichak	10.5±0.06	9.5±0.06	8.72±0.13	9.5±0.38	12.9±0.45	72±6.03
13	Neda	10.5±0.25	9.6±0.31	8.83±0.05	8.6±0.23	8.0±0.37	68±4.51
14	Patnai-231	7.5±0.15	6.6±0.06	6.05±0.02	12.0±0.53	8.3±0.33	62±5.20
15	Poushmoricha	7.7±0.66	6.6±0.13	5.93±0.06	14.3±0.25	10.2±0.23	59±5.51
Range		**7.0-10.7**	**6.2-9.6**	**5.74-8.83**	**8.6-14.5**	**4.0-20.0**	**59-78**
Mean±SD		**8.6±1.36**	**7.7±1.34**	**6.86±1.26**	**11.55±1.91**	**10.52±4.59**	**65.26±5.06**
CV%		**16**	**18**	**18**	**17**	**44**	**9**
SE (Standard error)		**0.211**	**0.112**	**0.316-01**	**0.709-01**	**0.972-01**	**1.52**
LSD (0.05)		**0.611**	**0.325**	**0.916-01**	**0.205**	**0.282**	**4.41**

Table-4.5.6: The Pearson correlation coefficient for protein digestibility, brown, milled and cooked rice protein as well as proteinloss ofmilled and cooked rice

Correlations

Parameters	**Protein digestibility (%)**	**Brown rice protein (%)**	**Milled rice protein (%)**	**Protein loss of milled rice (%)**	**Cooked rice protein (%)**
Protein digestibility (%)	1				
Brown rice protein (%)	.757**	1			
Milled rice protein (%)	.755**	.997**	1		
Protein loss of milled rice (%)	-.610*	-.757**	-.806**	1	
Cooked rice protein (%)	.694**	.956**	.963**	-.800**	1
Protein loss of cooked rice (%)	.105	.042	.025	.075	-.243

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table-4.5.7: Fractionation ofprotein (g/100g) for selected rice cultivars

Sl. No.	Cultivars	Albumin (g/100g)	Globulin (g/100g)	Prolamin (g/100g)	Glutelin (g/100g)
1	Neda	10.3	5.9	4.0	79.8
2	Dudhkalam	7.3	6.2	4.9	81.6
3	Athabinni	9.1	6.7	4.8	79.4
4	Magoibalam	12.2	5.0	4.8	78.0
5	Molladigha	8.3	4.6	4.3	82.8
6	Boylam	11.2	6.0	4.1	78.7
7	Karailadhan	9.1	4.6	4.5	81.8
8	Motichak	11.3	5.5	4.8	78.4
9	Jol	10.9	4.7	4.6	79.8
10	BRRI dhan28	9.6	5.3	4.4	80.7
Range		**7.3-12.2**	**4.6-6.7**	**4.0-4.9**	**78.0-82.8**
Mean±SD		**9.9±1.52**	**5.4±0.73**	**4.5±0.31**	**80.1±1.58**
CV%		**15**	**13**	**7**	**2**
SE(Standard error)		**0.5626**	**0.4485**	**0.3274**	**13.072**
LSD (0.05)		**1.671**	**1.3326**	**0.9729**	**38.839**

Table-4.5.8: The Pearson correlation coefficient of protein content with fractionation of protein for selected rice cultivars

Correlations				
Fractionation ofprotein	**Albumin (g/100g)**	**Globulin (g/100g)**	**Prolamin (g/100g)**	**Glutelin (g/100g)**
Albumin(g/100g)	1			
Globulin(g/100g)	-.168	1		
Prolamin(g/100g)	-.103	.105	1	
Glutelin(g/100g)	-.858**	-.323	-.148	1
Protein(g/100g)	.744*	-.277	-.411	-.502

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table-4.5.9: Amino acids composition for selected rice cultivars

Sl.No.	Amino Acids (g/100g)	BRRI dhan28	Neda	Athabinni	Magoibalam	Molladigha	Boylam	Karailadhan	Motichak	Jol	Range(g/100 g)	Mean± SD(g/100g)
1	Arginine	7.82	10.18	7.76	10.36	10.4	10.47	10.44	10.49	8.88	7.76-10.49	9.64±1.17
2	Lysine	3.63	3.79	3.44	4.29	4.15	4.27	3.34	4.25	3.65	3.34-4.29	3.87±0.38
3	Alanine	5.27	5.24	5.43	-	5.62	5.75	5.58	5.79	5.71	5.24-5.79	5.55±0.21
4	Threonine	3.78	3.8	3.45	3.97	3.34	3.92	3.41	3.94	3.74	3.34-3.97	3.71±0.24
5	Glycine	4.53	4.8	4.57	4.60	4.71	4.78	4.69	4.6	4.51	4.51-4.80	4.64±0.11
6	Valine	-	-	6.41	-	-	-	5.1	-	7.25	5.10-7.25	6.25±1.08
7	Serine	5.69	4.78	4.69	5.41	5.74	-	5.15	5.69	5.34	4.69-5.74	5.31±0.41
8	Proline	-	-	-	5.11	4.73	-	-	-	-	4.73-5.11	4.92±0.27
9	Isoleucine	4.33	-	-	-	-	-	-	-	-	4.33	0
10	Leucine	7.94	8.21	-	-	-	-	-	-	-	7.94-8.21	8.08±0.19
11	Methionine	-	2.19	-	-	2.09	-	2.23	-	-	2.09-2.23	2.17±0.07
12	Histidine	2.61	2.42	2.47	2.59	2.44	2.58	2.25	2.23	2.48	2.23-2.61	2.45±0.14
13	Phenylalanine	4.98	5.06	5.05	5.3	4.93	5.32	5.1	5.27	4.99	4.93-5.32	5.11±0.15
14	Glutamate	17.48	17.45	18.3	18.16	18.14	18.29	18.03	18.2	17.39	17.39-18.30	17.94±0.38
15	Aspartate	8.89	9.29	8.79	9.45	9.42	9.49	8.88	9.5	8.74	8.74-9.50	9.16±0.33
16	Cystine	1.36	1.97	2.03	2.37	2.39	2.4	2.09	2.33	2.13	1.36-2.40	2.12±0.33
17	Tyrosine	5.27	5.81	4.44	5.83	-	5.78	5.08	5.57	5.3	4.44-5.83	5.39±0.47
Amino acid percentage of protein (%)		**83.58**	**84.98**	**76.83**	**77.44**	**78.09**	**73.04**	**81.37**	**77.85**	**80.12**	**84.98-73.04**	**79.26±3.67**

Table-4.5.10: The Pearson correlation coefficient of protein content with amino acid composition for selected rice cultivars

***A.A.C. (g/100g)	Argenin	Lysine	Alanine	Threonine	Glycine	Valine	Serine	Proline	Isoleucine	Leucine	Methionine	Histidine	Phenylalanine	Glutamate	Aspartate	Cystine	Tyrosine
Argenine	1																
Lysine	.602	1															
Alanine	-.177	-.367	1														
Threonine	.187	.569	-.392	1													
Glycine	.672*	.280	.149	-.048	1												
Valine	-.459	-.733*	.257	-.469	-.446	1											
Serine	-.215	-.281	-.172	-.283	-.528	.141	1										
Proline	.357	.533	-.679*	-.089	.051	-.372	.265	1									
Isoleucine	-.587	-.236	.068	.115	-.402	-.246	.201	-.189	1								
Leucine	-.304	-.235	.098	.197	.128	-.372	.158	-.285	.647	1							
Methionine	.447	-.231	.220	-.576	.638	-.080	.204	.147	-.250	.204	1						
Histidine	-.399	.190	-.404	.302	-.146	-.204	-.327	.269	.428	.251	-.456	1					
Phenylalanine	.518	.597	-.427	.688*	.226	-.353	-.510	.042	-.332	-.346	-.400	-.010	1				
Glutamate	.339	.395	-.164	-.130	.206	-.121	-.331	.315	-.449	-.701*	-.132	-.163	.549	1			
Aspartate	.761*	.921**	-.294	.451	.563	-.826**	-.292	.475	-.310	-.117	.069	-.014	.608	.452	1		
Cystine	.729*	.623	-.204	.060	.369	-.076	-.298	.449	-.864**	-.773*	.062	-.248	.518	.639	.614	1	
Tyrosine	-.071	-.094	-.220	.716*	-.119	.064	-.265	-.539	.098	.232	-.443	.072	.564	-.226	-.106	-.222	1
Protein	.617	.882**	-.339	.577	.354	-.630	-.137	.466	-.374	-.043	-.037	.111	.422	.069	.835**	.585	-.032

*Correlation is significant at the 0.05 level (2-tailed).

Correlation is significant at the 0.01 level (2-tailed). * AAC = Amino Acid Composition

Table-4.5.11: Starch digestibility at different times with different amylose contentfor selected local rice cultivars

Amylose status	SL. No.	Cultivars	In vitro digestibility of starch (%)		
			0 (minute)	20 (minutes)	120 (minutes)
		Starch(CK)	14.39±0.3	73.87±1.2	90.4±2.3
High	1	Boradudkalam	4.48±0.3	52.39±1.3	63.3±2.7
	2	Boylam	5.13±0.5	60.66±1.2	73.87±2.3
	3	Depa	4.48±0.1	57.35±1.0	67.26±2.5
	4	Dudkalam	4.48±0.2	54.05±1.4	62.31±2.1
	5	Karailadhan	4.48±0.1	53.72±1.3	66.60±2.4
	6	Magoibalam	4.81±0.2	64.79±1.6	70.57±2.8
	7	Molladigha	4.48±0.2	58.01±1.4	65.78±2.2
	8	Motichak	5.80±0.2	61.32±1.4	75.53±2.5
	9	Patnai-231	4.48±0.4	55.70±1.5	65.61±2.2
	10	Poushmoricha	4.48±0.4	51.57±1.2	68.26±2.8
Intermediate	11	Neda	6.13±0.2	66.31±1.1	78.83±2.2
Low	12	Athabinni	7.78±0.2	68.92±1.1	83.79±2.2
	13	Kalabinni-1	6.96±0.1	65.61±1.3	80.48±2.9
	14	Kanaibanshi	6.46±0.4	67.93±1.0	81.31±2.2
	15	Ledabinni	6.79±0.5	65.12±1.1	83.46±2.3
Range			**4.48-7.78**	**51.57-68.92**	**62.31-83.79**
Mean±SD			**5.41±1.15**	**60.23±5.76**	**72.46±7.58**
CV%			**21**	**10**	**11**
SE (Standard error)			**0.55-01**	**0.334**	**0.310**
LSD (0.05)			**0.158**	**0.968**	**0.899**

Table-4.5.12: The Pearson correlation coefficient of starch digestibility at different times forselected local rice cultivars

Correlations

Time	**0 (minute)**	**20 (minutes)**
0 (minute)	1	
20 (minutes)	.806**	1
120 (minutes)	-.013	-.375

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

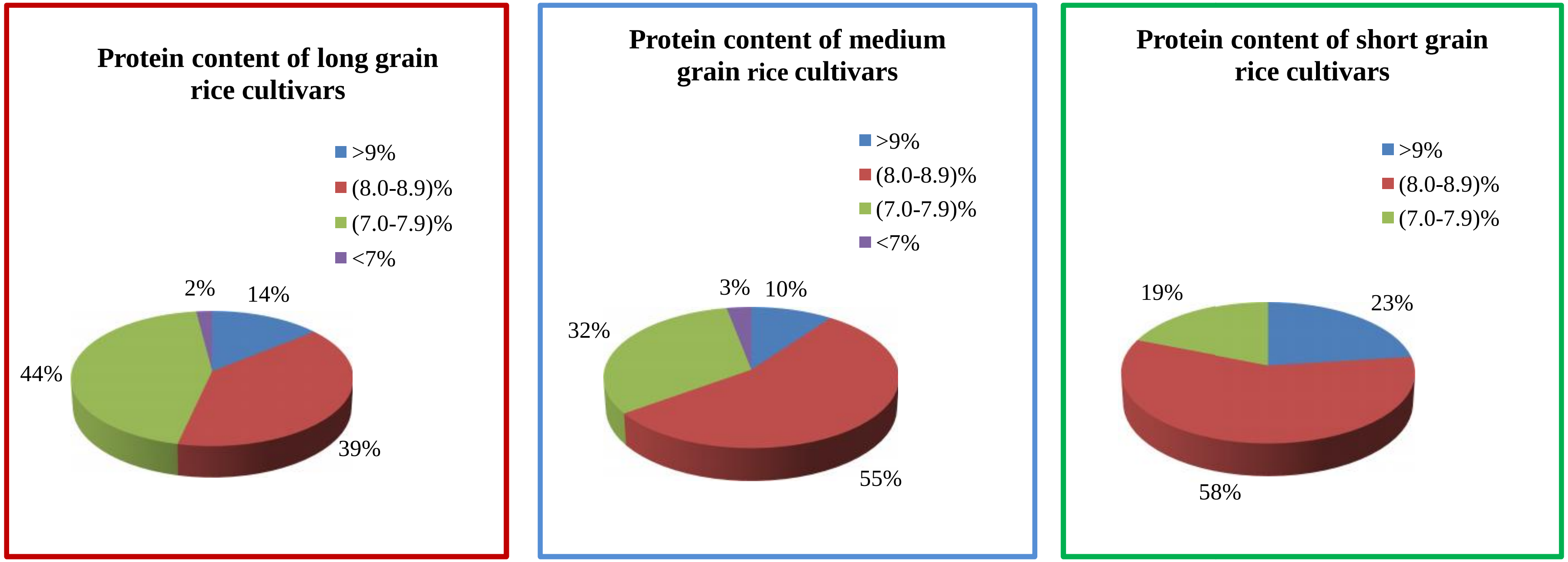

Figure-4.5.1: Frequency distribution of protein content for long, medium and short grain rice cultivars

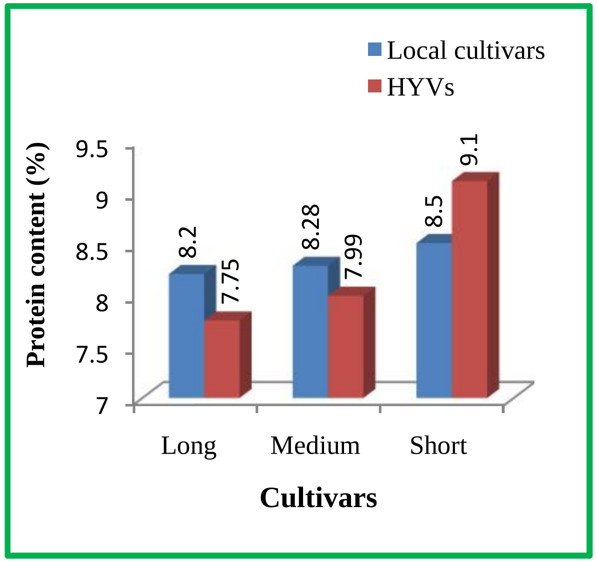

Figure-4.5.2: Comparison of protein content for long, medium and short grain local rice cultivars and HYVs

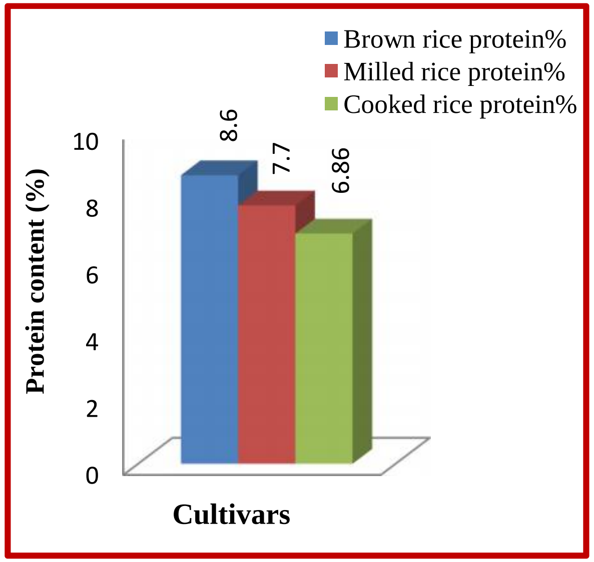

Figure-4.5.3: Comparison of brown, milled and cooked rice protein content forselected local rice cultivars

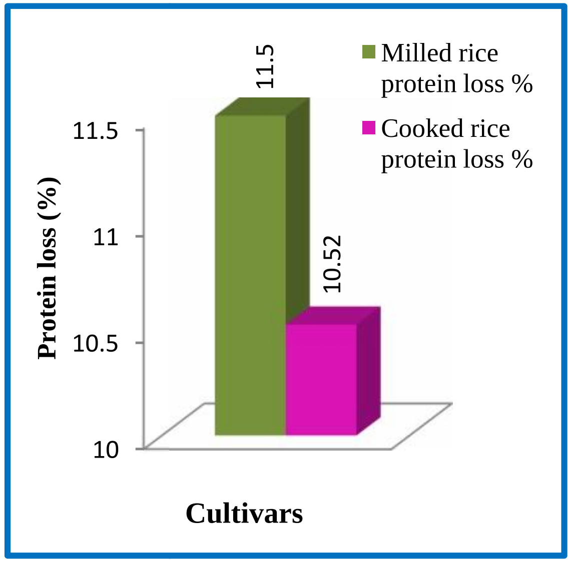

Figure-4.5.4: Comparison of milled and cooked rice protein loss forselected local rice cultivars

Figure-4.5.5: Frequency distribution of fractionation of protein(g/100g) and amino acid composition (g/100g) for selected rice cultivars

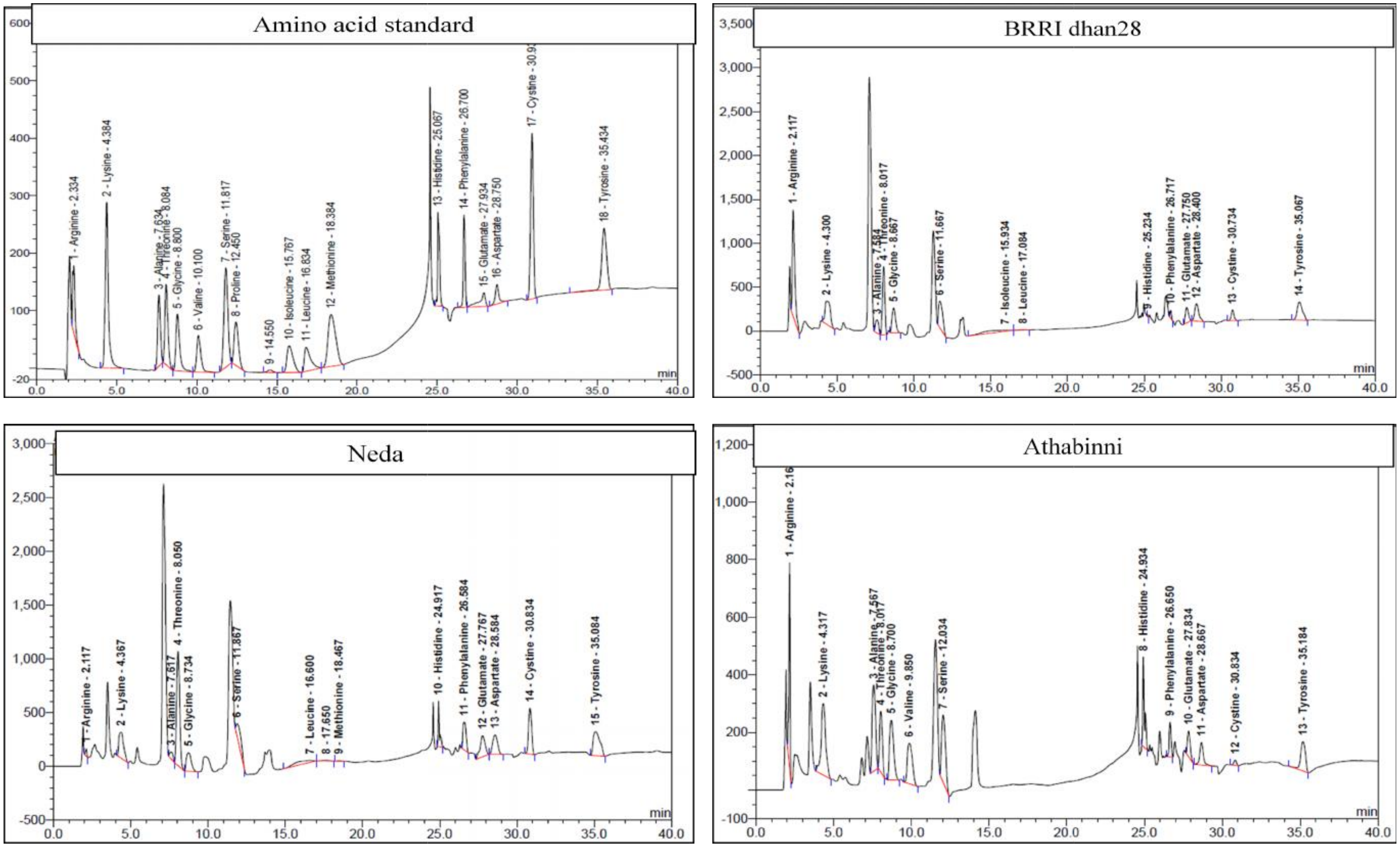

Figure-4.5.6a: Chromatogram of amino acids standard as well as amino acidsfor BRRI dhan28, Neda and Athabinni rice cultivars

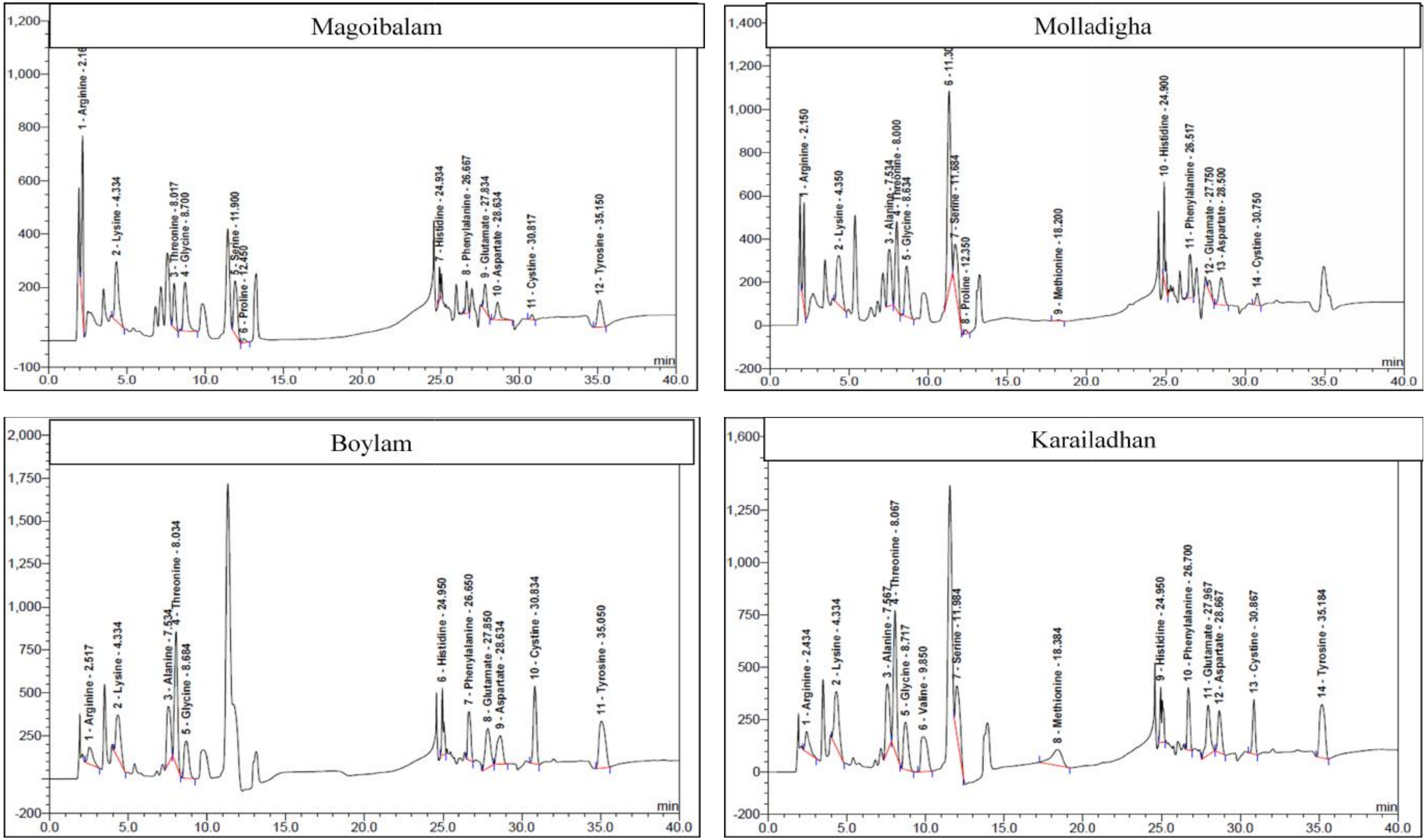

Figure-4.5.6b: Chromatogram of amino acidsforMagoibalam, Molladigha, Boylam and Karailadhan rice cultivars

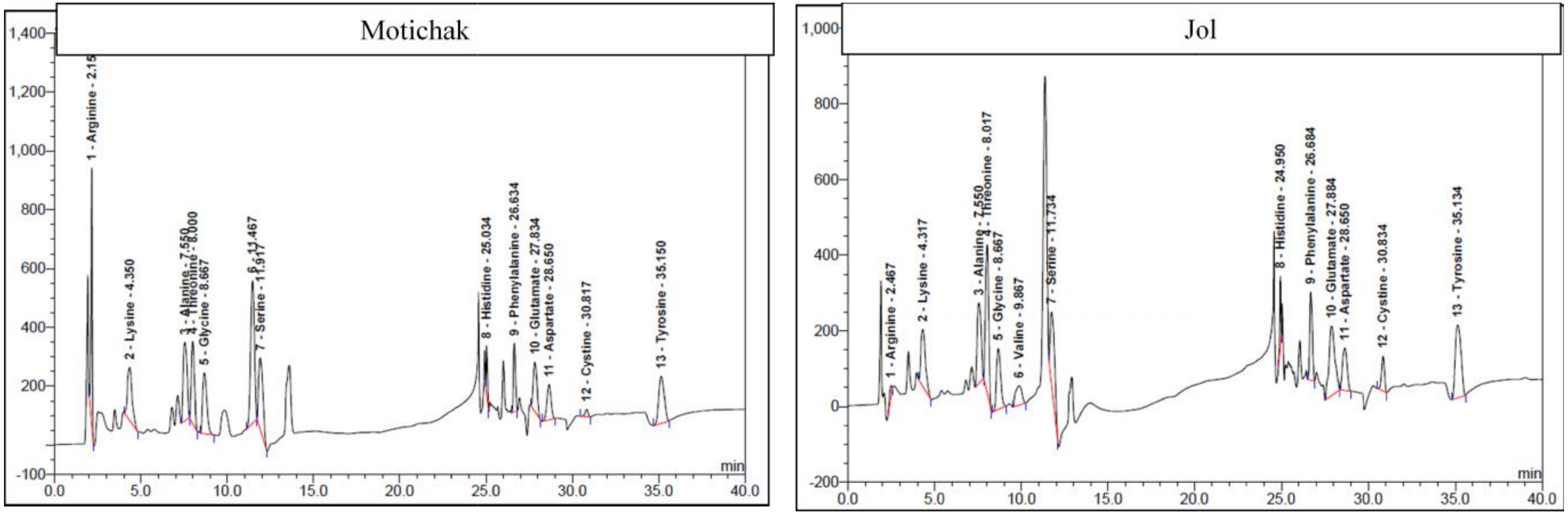

Figure-4.5.6c: Chromatogram of amino acidsforMotichak and Jol rice cultivars

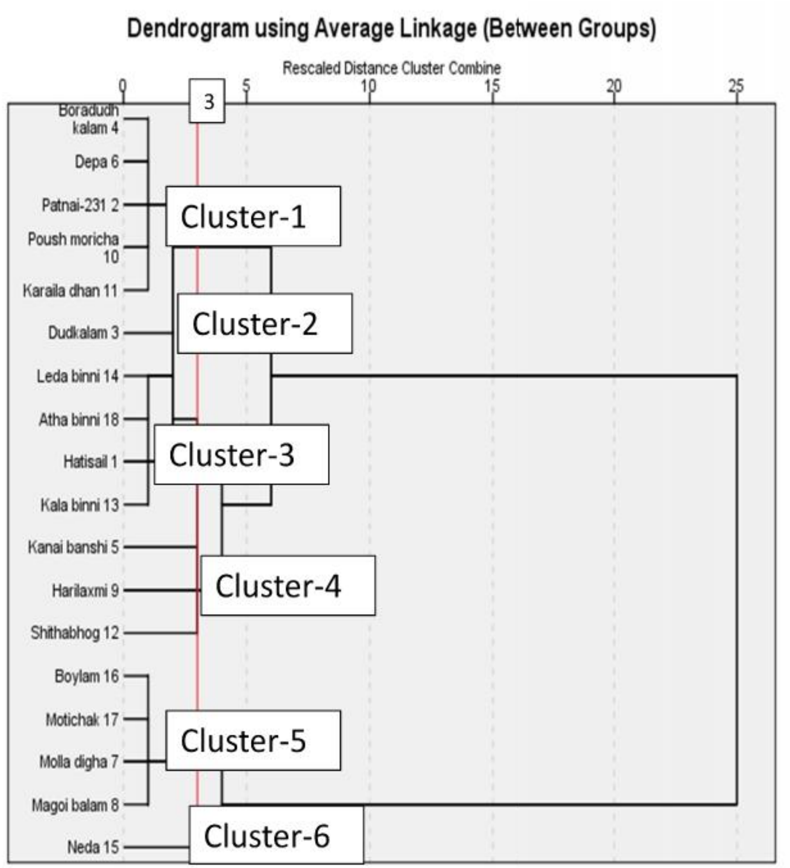

Figure-4.5.7: Dendrogram of selected local rice cultivars based on proximate composition

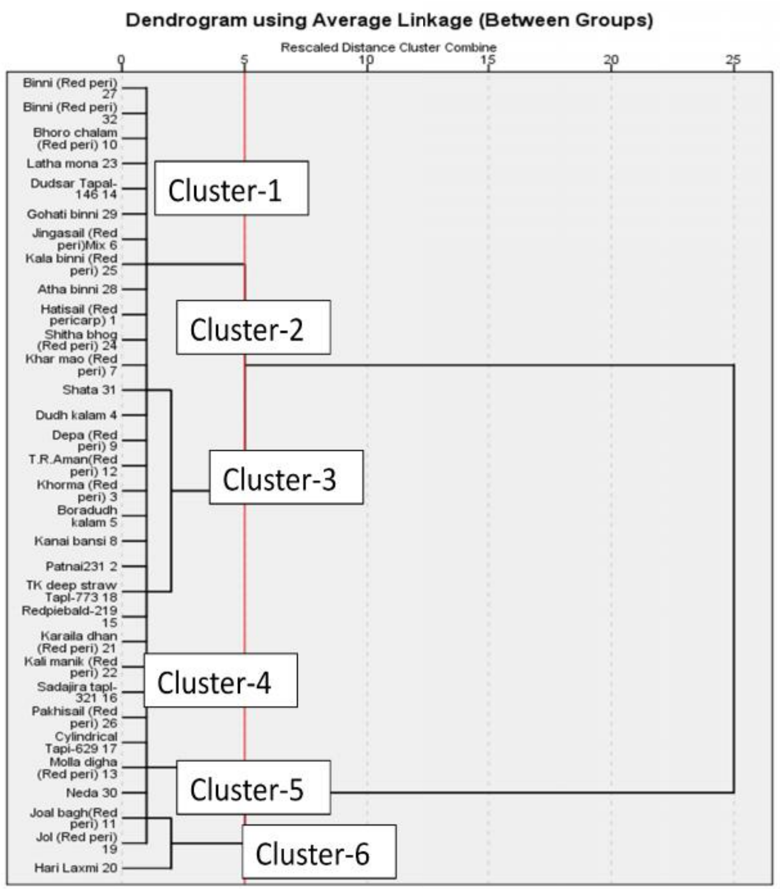

Figure-4.5.8a: Dendrogram of long grain local rice cultivars based on protein content

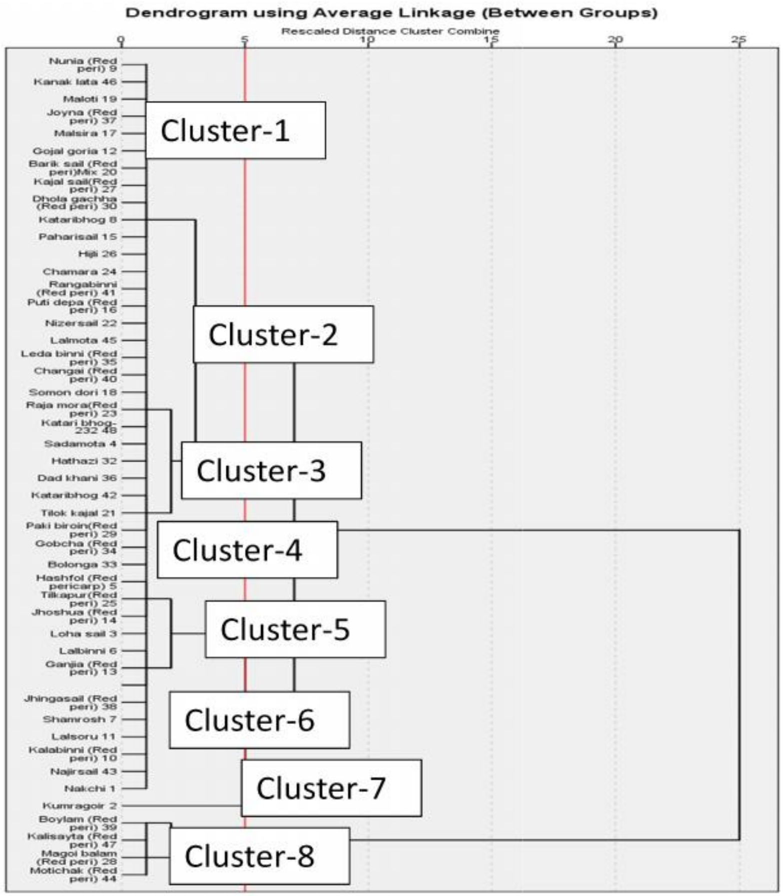

Figure-4.5.8b: Dendrogram of medium grain local rice cultivars based on protein content

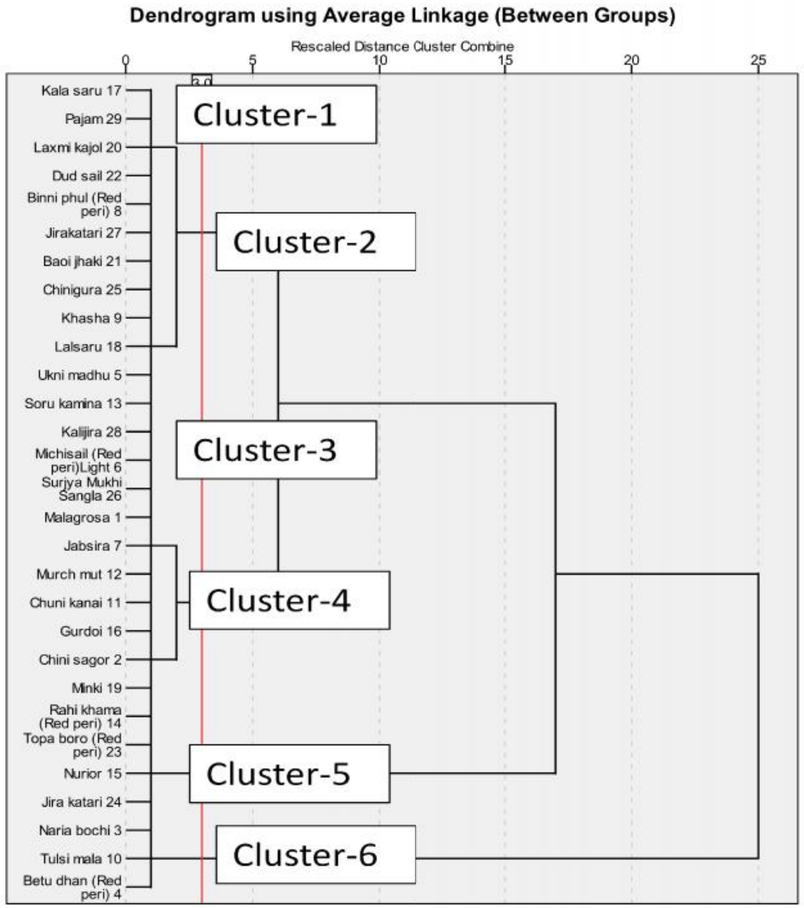

Figure-4.5.8c: Dendrogram of short grain local rice cultivars based on protein content

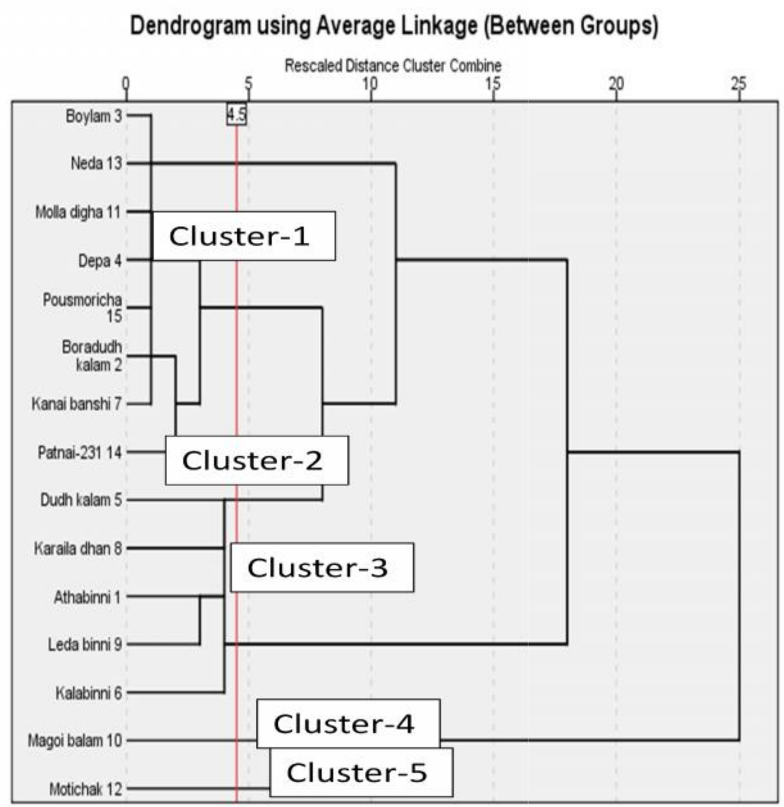

Figure-4.5.9: Dendrogram of local rice cultivars based on protein digestibility, protein content of brown, milled and cooked rice as well as protein loss of milled and cooked rice

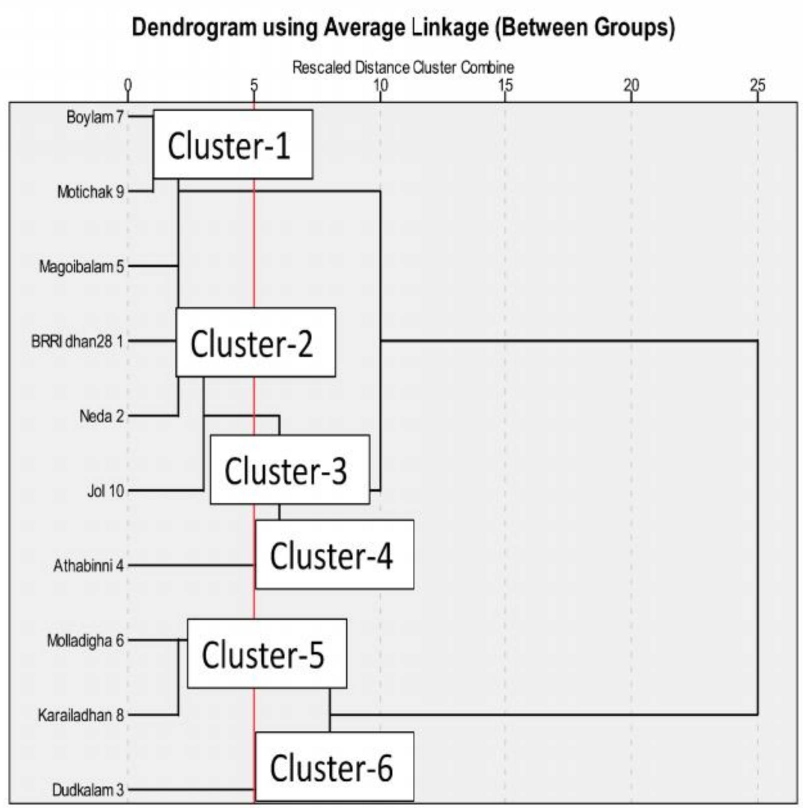

Figure-4.5.10: Dendrogram of selected rice cultivars based on fractionation of protein

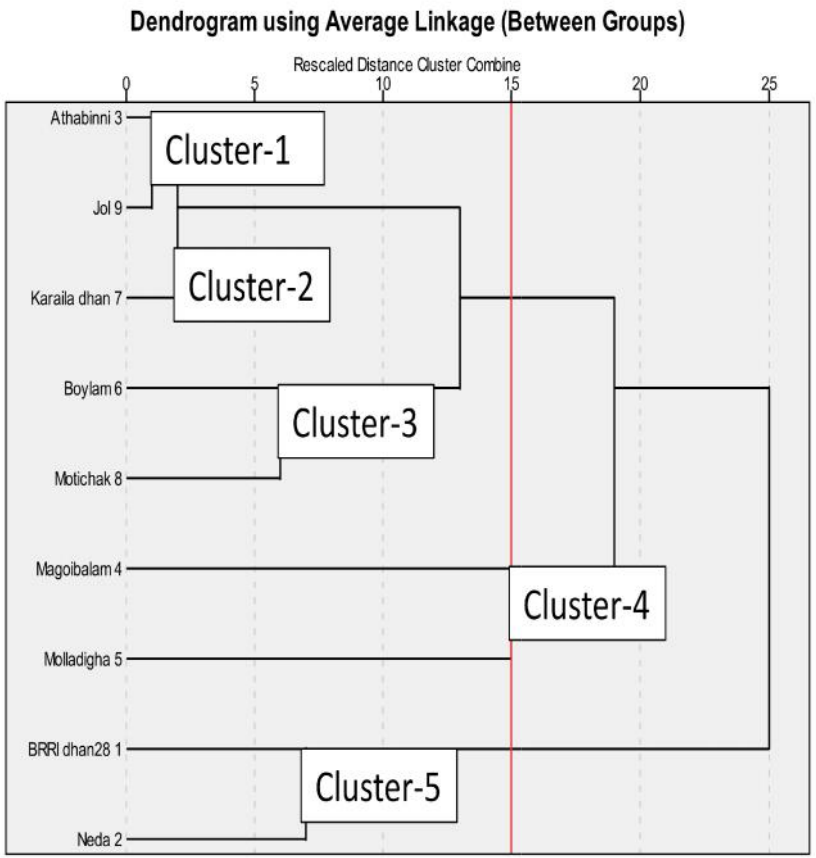

Figure-4.5.11: Dendrogram of selected rice cultivars based on amino acid composition

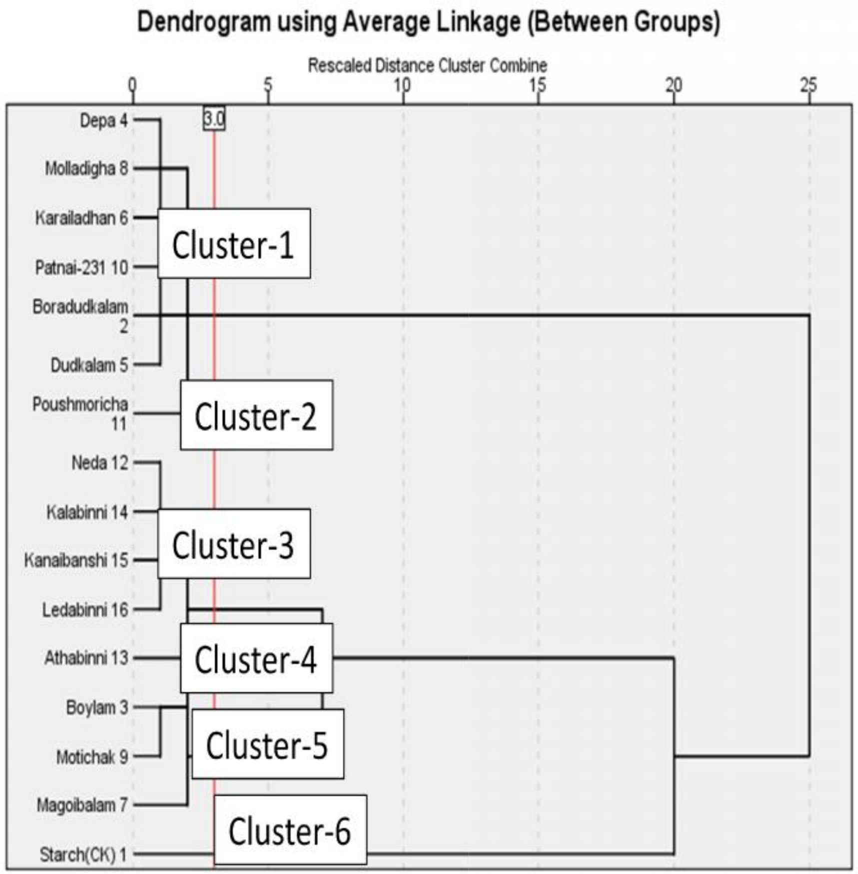

Figure-4.5.12: Dendrogram of local rice cultivars based on starch digestibility at different times with different amylose content for selected rice cultivars

Chapter 5

DISCUSSION

The study was conducted to identify promising rice cultivars for developing high yielding varieties with superior grain and nutritional quality. It included germplasm of 109 local rice cultivars and 20 HYVs from BRRI gene bank. Out of 129 rice cultivars, 36 were long; 62, medium and 31, short grain cultivars. I have analyzed the agronomic characters (grain yield, thousand grain weight, number of tiller/hill, number of panicle/hill, plant height, growth duration etc.), morphological and physical properties (panicle threshability, panicle type, awn status, pericarp color, chalkiness etc.), milling and cooking properties (milling outturn, head rice recovery, alkali spreading value, cooking time, elongation ratio etc.), content of mineral elements (Ca, P, Na, Zn etc.), nutritional quality (proximate composition, fractionation of protein, amino acid composition,starch and protein digestibility etc.), genetic diversity of *Waxy* geneas well as finally hybridization.

5.1 Agronomic characters

In the present study thousand grain weight, panicle length, number of panicle/hill and number of tiller/hill had very close relationship with yield but percent of filled grains had also close relationship with yield among the local rice cultivars. Plant height and growth duration both had close relationship with each other but weak relationship was found with yield among the local rice cultivars.

Grain yield: The number of panicles per area, the number of spikelets per panicle, the percent of filled grains per panicle and the weight of each grain refer to the structures of the rice plant that directly translate into yield. Grain yield of the total samples in this study varied from 0.9 t/ha to 5.6 t/ha among the rice cultivars including local cultivars and HYVs. The ranges of yield were (1.1-5.2) t/ha, (0.9-5.6) t/ha and (1.5-3.9) t/ha in long, medium and short grain rice cultivars, respectively.The range of yield obtained in the present study was higher than the data reported by Vange*et al*., 1999,(2.02-4.2) t/ha and Shahidullah, 2006, (1.42-4.21) t/ha yield of rice variety. But the range of yield obtained in the present study was lower than that data reported by Chandler, 1969, (6 t/ha) for the transplanted IR8 variety.

Thousand grain weight: It is an important and essential factor affecting grain yield. Thousand grain weight is determined by grain size and degree of grain filling. Thousand grain weight of the total samples in this study varied from 10.3 g to 38.1 g among the rice cultivars including local cultivars and HYVs. The ranges of thousand grain weight were(18.1-38.1) g, (12.1-31.7) g and (10.3-26.2) g in long, medium and short grain rice cultivars, respectively. The range of thousand grain weight obtained in the present study was higher than the data reported by Vange*et al*., 1999, (22.4-30.9) g; BRRI, 2000, (19.6-27.9) g; Iftekharuddaula, 2003, (16.89-27.48) g; Meena*et al*., 2010, (11.36-20.18) g and Juliana, 2012, (22.98-24.83) g thousand grain weight of rice.

Number of tiller/hill: Excessive tillering lead to high tiller abortion, poor grain setting, small panicle size and further reduced grain yield (Peng *et al*., 1994 and Ahmad *et al*., 2005). But Ibrahim *et al*., (1990) found that the number of productive tillers was the most reliable character to use in selecting genotypes. Because panicle number per plant was determined by effective tiller produced and those which survive for grain production. Number of tiller/hill of the total samples in this study varied from 9 to 17 among the rice cultivars including local cultivars and HYVs. The ranges of number of tiller/hill were (9-15), (9-17) and (9-17) in long, medium and short grain rice cultivars, respectively. The range of number of tiller/hill obtained in the present study was higher than thedata reported by Bashar, 2002, (7.2-12.8) and Sohel*et al*., 2009, (7.15-7.87) number of tiller/hill for rice variety. But the range of number of tiller/hill obtained in the present study was lower than that data reported by Shahidullah, 2006, (5-22) number of tiller/hill for rice variety.

Number of panicle/hill: Number of panicle per unit area is the most important component that contributes variations in yield directly. Number of panicle/hill of the total samples in this study varied from 6 to14 among the rice cultivars including local cultivars and HYVs. The ranges of number of panicle/hill were (7-11), (7-13) and (6-14) in long, medium and short grain rice cultivars, respectively. The range of number of panicle/hill of short grain rice cultivars obtained in the present study was higher than the data reported by Iftekharuddaula, 2003, (10.5-15.4) and Shahidullah, 2006, (4-11)number of panicle for rice variety. But the range of number of panicle/hill obtained in the present study was lower than that data reported by BRRI,2000,(16-27) forBR17 and BR1 variety.

Panicle length: Juliana, (2012) reported that the panicle length was an important trait which contributes to yield in rice because it determined the number of spikelets that would be produced. Panicle length of the total samples in this study varied from 18 cm to 30.8 cm among the rice cultivars including local cultivars and HYVs.The ranges of panicle lengthwere (21.7-30.8) cm, (20.8-29.3) cm and (18-29.2) cm in long, medium and short grain rice cultivars, respectively. The range of panicle length obtained in the present study was higher than the data reported by Bashar, 2002, (17.9-26.6) cm; Iftekharuddaula, 2003, (23.56-28.75) cm and Shahidullah, 2006, (21.12-29.15) cm for rice variety.

Plant height: Rice plant height is an important trait linked to plant type and yield potential. It is a major factor for determining rice grown area because rice grows under irrigated, rainfed and deepwater condition. Plant height of the total samples in this studyvaried from 86.4 cm to 205.2 cm among the rice cultivars including local cultivars and HYVs. The ranges of plant height were (106-179.6) cm, (100-205.2) cm and (86.4-193.2) cm in long, medium and short grain rice cultivars, respectively. The range of plant height obtained in the present study was too much higher than the data reported by Bashar, 2002, (80.7-151.2) cm; Iftekharuddaula, 2003, (93.8-110.3) cm; Shahidullah, 2006, (98.23-162.76) cm and Juliana, 2012, (109.62-152.75) cm for rice variety.

Growth duration: The length of time from establishment to harvest is known for each rice cultivar. It may vary depending on the growing conditions especially water availability and solar radiation. BRRI developed short growth duration varieties for accommodating other crops to increase cropping intensity and long growth duration varieties for deep water rice. Growth duration of the total samples in this studyvaried from 106 days to 174 days among the rice cultivars including local cultivars and HYVs. The ranges of growth duration were (115-171) days, (106-174) days and (107-155) days in long, medium and short grain rice cultivars respectively. The range of growth duration obtained in the present study was higher than the data reported by BRRI, 2000, (147-166) days; Bashar, 2002, (97-138) days; Iftekharuddaula, 2003, (113.3-131) days and Shahidullah, 2006, (116-154) days for rice variety.

Percent of filled grains: Grain filling is important for improving rice yield potential. The percentage of filled grains depends on the grain filling rate of superior and inferior grains. Growing conditions can also influence the percentage of filled grains. In lowland rice, for example, drought stress during late panicle development sharply decreases the percentage of filled grains. Percent of filled grains of the total samples in this study varied from 39% to

98% among the rice cultivars including local cultivars and HYVs. The ranges of percent of filled grains were (54-97)%, (39-98)% and (54-95)% in long, medium and short grain rice cultivars respectively. The range of percent of filled grains obtained in the present study was higher than the data reported by Iftekharuddaula, 2003, (80.3-90.8)%and Shahidullah, 2006, (56.4-91.5)%. But the data reported by Chandler, 1969, (85% filled spikelets)for the transplanted IR8 variety was within the range that found in the present study.

Correlation of agronomic characters: Correlation between grain yield and yield components of agronomic characters has been studied extensively at the phenotypic level. In long grain rice cultivars, thousand grain weight and panicle length were significant and positively correlated with yield. Number of panicle/hill was positively correlated with yield. Plant height was significant and positively correlated with panicle length. In medium grain rice cultivars, thousand grain weight and number of tiller/hill were positively correlated with yield. Number of panicle/hill, panicle length and percent of filled grains were significant and positively correlated with yield. Not only that but percent of filled grains was also significant and positively correlated with growth duration. Plant height was positively correlated with thousand grain weight and panicle length. In short grain rice cultivars, thousand grain weight, number of tiller/hill, plant height and growth duration were positively correlated with yield. Growth duration was also positively correlated with thousand grain weight. Plant height was highly significant and positively correlated with panicle length.

The findings of this present study agreed with many other published reports. Grain traits had a positive association with grain yield per plant (Deshmukh and Chau, 1992). The number of filled grains per panicle and thousand grain weight were found positively correlated with yield (Mehetre*et al*., 1994; Samonte*et al*., 1998 and Surek*et al*., 1998). Subramanian and Rathinam, (1984) observed highly significant associations of grain yield with thousand grain weight and number of tillers per plant. Sharma and Choubey, (1985) as well as Dhanraj and Jagadish, (1987) reported that yield/plant was positively correlated with the number of productive tillers, number of panicles and thousand grain weight. Bai *et al*., (1992) reported that the correlations of yield with number of productive tillers. Similarly, Ram, (1992) reported significant positive associations of yield with thousand grain weight and number of productive tillers per plant. Surek*et al*., (1998) reported that grain yield/plant was significantly correlated with number of panicles per plant and thousand grain weight. Surek and Beer, (2003) observed significant associations of grain yield with number of productive tillers per square meter and number of filled grains per panicle. Sharma, (1997) reported that grain yield/plant showed positive and significant correlation with thousand grain weight, grains/panicle and plant height. Gomathinayagam*et al*., (1988) obtained positive and significant correlation of grain yield with growth duration and plant height in upland rice varieties. Yadav *et al*., (2010) revealed that the correlation coefficient between seed yield per plant and other quantitative attributing to yield showed that grain yield was significantly and positively associated with number of tillers per hill, number of panicle per plant, panicle length and number of spikelets per panicle at phenotypic levels.

5.2 Morphological and physical properties

Qualitative characters are important for plant description (Kurlovich, 1998) and mainly influenced by the consumers preference, socio-economic scenario and natural selection (Hien *et al.*, 2007). Panicle threshability, panicle type, presence and absence of awn, hull color, pericarp color, chalkiness and appearance are not directly related to yield. But farmer preferences regarding these components vary from one location to another. The farmer's and miller's concern is to get high price of produce paddy and rice which is determined by market quality standards comprising of size and shape as well as color of rice (Ahuja *et al.,* 1995). Rice grains vary in length, shape and color as well as are of great importance to consumers, producers and breeders because most of the rice produced in the world is consumed as a whole grain (Taylor and Parker, 2002).

Panicle threshability: Many traditional rainfed lowland rice cultivars shatter normaly due to easy panicle threshability. So, farmers need shattering resistant cultivars to reduce the yield loss during harvesting and transportation of rice cultivars before threshing. Difficult threshability of panicle requires much time and excess energy. Only, intermediate panicle threshability is perfect and friendly for the farmers.Among 129 rice cultivars of long, medium and short grain, 67 (53%) were difficult; 56 (42%) were intermediate and 6 (5%) were easy panicle threshability. The highest amount of difficult, higher amount of intermediate and the lowest amount of easy panicle threshability were found but loose panicle threshability was not found in this study. The data of the present study varied to the data reported by Rita and Sarawg, 2008;among 32 germplasm cultivars, 8 (25%) were intermediate, 16 (50%) were loose and 8 (25%) were easy panicle threshabilityas well as Asif *et al.,* 2009; among 150 rice varieties, 23 (15.3%) were difficult, 50 (33.3%) weremoderately difficult, 38 (25.3%) were intermediate, 31 (20.7%) were loose and 8 (5.3%) were easy panicle threshability.

Panicle type: Filled grain rate varied with grain position within panicle. Panicle is a key organ for rice yield formation and panicle type has received much attention recently (Komatsu *et al.,* 2001; Yamagishi *et al.,* 2002 and Ikeda *et al.,* 2010). Among 129 rice cultivars of long, medium and short grain, 48 (37%) werecompact, 66 (51%) were intermediate and 15 (12%) wereopenpanicle type. The highest amount of intermediate, higher amount of compact and the lowest amount of open panicle type rice cultivars were found but bunchy panicle type rice cultivars was not found in this study. The data of the present study was similar to that data reported by Rita and Sarawg, 2008; among 32 germplasm cultivars, 13 (40.6%) cultivars were compact, 18 (56.3%) cultivars were intermediate and 1 (3.1%) cultivar was open panicle type.

But the data of the present study varied to the data reported by Zafar *et al.,*2004; among 124 long grain accessions, 33 (26.6%) were compact panicle type, 47 (37.9%) were intermediate panicle type and 44 (35.48%) were open panicle type;Asif *et al.,*2009;among 150 rice varieties, 70 (46.6%) varieties werecompact, 37 (24.6%) varieties were intermediate and 43 (28.6%) varieties were open panicle type as well asChaudhari*et al.,* 2014; among 121 rice cultivars, 50 (41.3%) were compact and 71 (58.7%) were bunchy panicle type.

Awn status: Awn is found at the tip of the spikelet. Farmers prefer awnless grain for friendly use in threshing, drying and milling time. Among 129 rice cultivars of long, medium and short grain, 112 (87%) wereawnlessbut 17 (13%) were awn. Higher amount of awnless cultivars were found but awnletted cultivars were not found in this study. The data of the present study was similar to the data reported by Shahidullah, 2006; among the 40 varieties, 11 (27.5%) were awn on their spickeletsbut 29 (72.5%) wereawnless; Rita and Sarawg, 2008; among 32 germplasm cultivars, 31 (96.9%) wereawnlessbut 1 (3.1%) was awnas well as Chakravorty and Ghosh, 2011; among 51 rice cultivars, 36 (70.6%) cultivars wereawnlessbut 15 (29.4%) cultivars were awn.But the data of the present study varied to that data reported by Zafar *et al.,*2004; 53 (42.7%) accessions wereawnlessand 45 (36.3%) were awn, whereas 26 (21%) accessions were found awnletted among the 124 long rice grain accessions.

Hull color: Covered grains of rice with different hull colors are harvested as paddy. People prefer golden or straw hull colored paddy among the rice cultivars. Among 129 rice cultivars of long, medium and short grain, 54 (41.9%) were golden hull color of whole paddy; 7 (5.4%) were golden with different mixed hull color of whole paddy; 29 (22.5%) were straw hull color of whole paddy; 18 (13.9%) were black hull color of whole paddy; 2

(1.6%) were black with different mixed hull color of whole paddy as well as 19 (14.7%) were purple hull color of whole paddy. Golden, golden with different mixed, straw, black, black with different mixed and purple hull color paddy were found but brown and white hull color paddy were not found in this study.

The data of the present study varied to the data reported by Shahidullah, 2006; among the 40 varieties, 21 (52.5%) were straw, 3 (7.5%) were black, 3 (7.5%) were brown, 4 (10%) were brown spots on straw, 8 (20%) were gold and gold furrows on straw as well as 1 (2.5%) was brown furrows on straw background of lemma and palea (hull) color; Rita and Sarawg,2008; among 32 germplasm cultivars, 13 (40.6%) were straw, 3 (9.4%) were gold and gold furrow on straw background, 15 (46.9%) were brown as well as 1 (3.1%) was black lemma and palea (hull) colorand Asif *et al.*,2009; among the rice varieties, 30 (21.9%) were straw, 32 (23.4%) were gold and gold furrows on straw background, 18 (13.1%) were brown spots on straw, 8 (5.8%) were brown furrows on straw, 4 (2.9%) were brown (tawny), 5 (3.6%) werereddish to light purple, 6 (4.4%) were purple spots on straw, 7 (5.1%) were purple furrows on straw, 8 (5.8%) were purple, 9 (6.6%) were black as well as 10 (7.3%) were white lemma and palea (hull) color.

Pericarp color: Grain color is another measure for grain and nutritional quality of rice. Most of the people habituate to eat white milled rice as edible rice. Chinese researchers found that red rice contains considerable amount of iron and zinc. It is generally believed that some of the colored pericarp rice varieties have medicinal properties (Oki *et al.,* 2004). Among 129 rice cultivars of long, medium and short grain, 46 (36%) cultivars were red and 83 (64%) cultivars were brown pericarp color. Whereas yellow, golden and straw pericarp colors were not found in this study. The data of the present study varied to the data reported by Zafar *et al.,* 2004; pericarp color exhibited great variability ranging from different shades of brown to a variable range of purple color but no accession was found with red pericarp color in the long grain rice cultivarsand Chaudhari*et al.,* 2014; among 121 rice cultivars, 21 (17.3%) were yellow, 22 (18.2%) were golden, 38 (31.4%) were straw, 30 (24.8%) were brown and 10 (8.3%) were reddish brown pericarp color.

Size and shape: Grain size and shape is the first criteria for rice grain quality, breeder considersthat in developing new varieties for release of commercial production reported by Adair *et al.*,(1966). So, the grain size and shape is an important preferable quality indicator for the consumers. Among 129 rice cultivars of long, medium and short grain, 16 (12.4%) were long slender, 20 (15.5%) were long bold, 3 (2.3%) were medium slender, 53 (41.1%)

weremedium bold, 6 (4.7%) were medium round, 19 (14.7%) were short bold as well as 12 (9.3%) wereshort round type size and shape. Seven types of grain size and shape for rice cultivars were found in this study. The data of the present study was similar to that statement reported by Biswas *et al.*,1992andSiddiquee*et al.*,2002; grain size and shape of some modern rice, some local aromatic rice, some balam rice and some local Aus cultivars in Bangladesh varied from long slender to short bold grain.

But the data of the present study varied to the data reported by Hasiba*et al*.,2006; Porabinni was long slender and Kataribhog was medium slender grain; Asif *et al.*,2009; among the accessions, 56 (49.1%) were short bold, 50 (43.9%) were short slender, 4 (3.5%) were medium slender and 4 (3.5%) were long slender kernels; Shilpa*et al.*,2010; among 22 traditionally cultivated rice varieties with 3 high yielding rice varieties, 4 (16%) were long slender, 8 (32%) were long bold, 5 (20%) were medium slender and 8 (32%) were short bold grainsas well asAngelita*et al.*, 2011; among 37 rice cultivars, 6 (16.2%) were long slender, 20 (54.1%) were long bold and 11 (29.7%) were medium bold size and shape.

Chalkiness: Chalkiness in the rice grain is a negative quality factor; it influences consumers' preference and milling yield. The chalky portion of the grain is not hard enough. As a result, the varieties with chalkiness in the grain tend to break more frequently during milling. It is formed when irregular packing of starch granules occurred during the grain-filling stages of reproductive development or creating air spaces in the endosperm of rice kernels that result in opaque white regions of the kernel (Ashida*et al.*, 2009). Among 129 rice cultivars of long, medium and short grain, 85 (66%) cultivars were translucent, 26 (20%) cultivars were white belly, 8 (6%) cultivars were white center and 10 (8%) cultivars were opaque grain. Translucent grain were mostly found but some chalky grain (among three types) were also found in this study.

The finding of the present study was almost similar to the finding reported by Biswas *et al.*,1992; the grains from most of the modern high yielding varieties and local aromatic balam rice in Bangladesh were translucent as well asSiddiquee*et al.*, 2002a; most of the local Aus varieties were different degrees of chalkiness.The finding of the present study varied to the finding reported by Hasiba*et al.*, 2006; Nizersail and Kataribhog were translucent grain, Latasail was white belly grain as well as Porabinni, Rangabinni and Mouberuin were opaque grain; Shilpa*et al.*,2010; among 22 traditionally cultivated rice varieties with 3 high yielding rice varieties, 19 (76%) were white belly and 6 (24%) were white center type of chalkinessas well asAngelita*et al.*,2011; among 37 rice cultivars, 18 (48.6%) were small chalkiness and 19 (51.4%) were medium chalkiness.

Appearance: Appearance of milled rice is one of the most important factors to accept a variety by the consumers. It is the combination of all quality parameters. Webb, (1985) reported that grain appearance of rice indicates size, shape, color, chalkiness and translucency. The rice varieties having either translucency or minimum amount of chalkiness is consider as good quality grains in comparison with chalky once which decreases the rice grain quality. Among 129 rice cultivars of long, medium and short grain, 1 (1%) cultivar was excellent, 21 (16%) cultivars were very good and 107 (83%) cultivars were good appearance. Three types of grain appearance for rice cultivars were found in this study. The data of the present study varied to the data reported by Hasiba*et al.*,2006; Nizersail was very good appearance as well as Latasail, Mouberuin and Porabinniwere good appearance but excellent appearance was absentand Shilpa*et al.*,2010; among 22 traditionally cultivated rice varieties with 3 high yielding rice varieties, 2 (8%)wereexcellent, 7 (28%) were good and 16 (64%) were acceptable appearance but very good appearance was absent.

Length, breadth and L/B ratio of paddy, brown rice and milled rice: Length of paddy influences farmers and millers. Length of milled rice is an important physical property that attracts consumer's attention. Length to breadth ratio determines the grain shape. The higher L/B ratio gives finer grain shape. It indicates very good appearance of rice grain. Among 129 rice cultivars of long, medium and short grain, paddy length varied from 5.8 mm to 12.1 mm; paddy breadth varied from 2.1 mm to 3.5 mm and paddy L/B ratio varied from 1.9 to 5.2. The variation of length, breadth and L/B ratio for paddy in the present study was higher than that data reported by Hasiba*et al.*,2006; length of paddy varied from 7.6 mm to 9.7 mm in modern and 7.9 mm to 9.5 mm in local varieties; breadth of paddy varied from 1.9 mm to 2.5 mm in modern and 2.0 mm to 2.7 mm in local varieties as well as L/B ratio of paddy varied from 3.04 to 4.50 in modern and 3.19 to 4.10 in local variety.

Among 129 rice cultivars of long, medium and short grain, brown rice length varied from 4.0 mm to 8.3 mm; brown rice breadth varied from 1.8 mm to 3.0 mm and brown rice L/B ratio varied from 1.5 to 4.3. The variation of length, breadth and L/B ratio for brown rice in the present study was higher than that data reported by Hasiba*et al.,* 2006; length of brown rice varied from 5.4 mm to 7.1 mm in modern and 5.7 mm to 6.6 mm in local varieties; breadth of brown rice varied from 1.9 mm to 2.3 mm in modern and 1.8 mm to 2.5 mm in local varieties as well as L/B ratio of brown rice varied from 2.5 to 3.6 in modern and 2.3 to 3.2 in local variety.

Among 129 rice cultivars of long, medium and short grain, milled rice length varied from 3.7 mm to 7.4 mm; milled rice breadth varied from 1.6 mm to 2.9 mm and milled rice L/B ratio varied from 1.4 to 4.2. The variation of length, breadth and L/B ratio for milled rice in the present study was higher than the data reported by Hasiba*et al.*,2006; Length of milled rice varied from 5.2 mm to 6.4 mm in modern and 5.4 mm to 6.1 mm in local varieties; breadth of milled rice varied from 1.8 mm to 2.1 mm in modern and 1.7 mm to 2.3 mm in local varieties as well as L/B ratio of milled rice varied from 2.5 to 3.3 in modern and 2.5 to 3.2 in local variety; Yadav *et al.*,2007; Length and breadth of milled raw rice varied from 5.85 to 8.25 mm with high value and 1.65 to 2.93 mm; Devi *et al.*,2008a; Rice kernel length roughly varied from 5.0 to 7.5 mm and breadth from 1.9 to 3.0 mm as well asMeena*et al.*,2010;the grain length varied from 4.30 to 7.80 mm, breadth 1.84 to 2.27 mm and L/B ratio 2.02 to 4.22.Butthe length and L/B ratio for milled rice in the present study was lower than that data reported by Kamath *et al.*,2008; Basmati milled rice had the highest grain length (7.63 mm) and L/B ratio (4.48).

Correlation of length, breadth and L/B ratio: The relationship among length, breadth and L/B ratio of paddy, brown rice and milled rice has been studied extensively. Different combinations of these traits within the cultivars have been shown in this study.Milled rice length was positively correlated with milled rice (L/B) ratio and milled rice breadth. Similarly, milled rice breadth was positively correlated with milled rice (L/B) ratio. The statement of this study partly agreed and partly disagreed with that statement reported by Tehrim*et al.,* 2012; grain length displayed highly significant positive correlation with grain length-breadth ratio, while highly significant negative association with grain breadth. On the other hand grain breadth revealed highly significant negative correlation with grain length-breadth ratio.

5.3 Milling and cooking properties

The greatest amount of total milling outturn and the highest proportion of head rice recovery to broken are the good indicator of milling quality. Cooking quality of rice is the best choice of the consumers. So, cooking behavior is one of the important determinants of rice quality (Feillet and Marie, 1979). Grain elongation and aroma are the key determinant of high quality rice varieties revealed by Golam *et al.,* (2004). If rice elongates more lengthwise it gives a finer appearance but if it expands girth-wise, it gives a coarse look (Anonymous, 1997 and Danbaba*et al.*, 2011). Additionally, gelatinization temperature can influence cooking and eating qualities of rice, which can vary based on the varieties (Bhattacharya *et al.*, 1971 and Juliano, 1972). Consumer and traders prefer quality of rice. So, rice quality is a major determinant of price in the paddy markets of many countries, including the United States (Brorsen *et al.*, 1984).

Milling outturn: Milling outturn is the amount of milled rice from unit quantity of rough rice. Merca and Juliano, (1981) reported that milling outturn is one of the important properties to the millers. Milling outturn of the total samples in this study varied from 59% to 74% among the rice cultivars including local cultivars and HYVs. The ranges of milling outturnwere(63-71)%, (59-74)% and (59-72)% in long, medium and short grain rice cultivars, respectively. The range of milling outturn obtained in the present study was higher than the data reported by Palacpac, 1982, (60-73)%; Biswas *et al.*, 1992, (69-73)%;Biswas *et al.*,2000, (64-72)%; Zhou *et al*., 2002, (64-70)% and Deepa, 2004, (62.8-73.3)%for tested rice varieties.

Head rice recovery: Head rice recovery is the amount of whole milled rice in the total milled rice. Brorsen*et al.*, (1984) reported that head rice recovery after milling was defined as milling quality. Head rice recovery was associated with hardness of the endosperm reported by Goodman and Rao, (1985). The soft region of the endosperm contributes to grain breakage during milling.Any breakage of the grain during milling is undesirable. Head rice recovery of the total samples in this study varied from 26% to 98% among the rice cultivars including local cultivars and HYVs. The ranges of head rice recovery were(41-96)%, (26-98)% and (75-98)% in long, medium and short grain rice cultivars, respectively. The range of head rice recovery obtained in the present study was higher than the data reported by Biswas *et al.*, 2000,(52-98)% and Deepa, 2004, (32.9-95.7)% for tested rice varieties.

Hull content: Hull (lemma and palea) is the covering structure of the brown rice. Rice hull provides protection to the brown rice from fungal infestation and protection from the outside injury. Hull content of the total samples in this study varied from 19% to 27% among the rice cultivars including local cultivars and HYVs.The ranges of hull content were(21-27)%, (19-26)% and (20-26)% in long, medium and short grain rice cultivars, respectively. The range of hull content obtained in the present study was higher than that data reported by Hasiba*et al.*, 2006; hull content of tested rice varieties varied from 18.5%

to 24.0%. But the range of hull content obtained in the present study was lower than the data reported by Juliano, 1972, (16.0-28.0)%andDeepa, 2004, (19-29.6)%for tested rice varieties.

Alkali spreading value: Alkali spreading value is important parameter for cooking quality. It determines the gelatinization temperature. Alkali spreading value has the inverse relationship with gelatinization temperature. Alkali spreading value of the total samples in this study varied from 3.2 to 7.0 among the rice cultivars including local cultivars and HYVs. The ranges of alkali spreading value were (3.2-7.0), (3.8-7.0) and (3.7-6.4) in long, medium and short grain rice cultivars, respectively. The range of alkali spreading value obtained in the present study wasalmost similar to that data reported by Asghar*et al.*,2012, (3.1-7.0) for rice varieties. But the range of alkali spreading value obtained in the present study was higher than that data reported by Hasiba*et al.*,2006, (3.9-7.0) for tested rice varieties.

Gelatinization temperature: Chrastil*et al.*, (1992) reported that gelatinization temperature, which is very important test to determine the cooking quality of rice. Consumer prefers intermediate gelatinization temperature than low and high gelatinization temperature. Eighty two were intermediate but 47 were low gelatinization temperature among long, medium and short grain rice cultivars including local cultivars and HYVs. Intermediate gelatinization temperature was higher than low gelatinization temperature in this study. The finding of this study was similar to the data reported by Juliano, 1964; traditional tropical rice was generally of intermediate gelatinization temperatureand Biswas *et al.*, 2000; all tested varieties had intermediate gelatinization temperature. But the finding of this study was dissimilar to that data reported by Hasiba*et al.*, 2006; all modern and local tested rice varieties had low gelatinization temperature except two.

Cooking time: Consumer prefers cultivar with short cooking time for energy saving. Cooking time of the rice depends on coarseness, protein content, amylose content and starch gelatinization temperature. Moreover, small and slender grains cook faster than big and round grains. Longer cooking duration resulted in greater moisture content of cooked rice producing softer rice. Cooking time of the totalsamples in this study varied from 13 minutes to 23 minutes among the rice cultivars including local cultivars and HYVs. The ranges of cooking time were (15-23) minutes in long as well as (13-23) minutes in both medium and short grain rice cultivars.The range of cooking time obtained in the present study washigher than the data reported by Hasiba*et al.*, 2006,(14-20) minutes and Diako*et al.*, 2011, (15.31-23.27) minutes for tested rice cultivars. But the range of cooking time obtained in the present study waslower than that data reported by Biswas *et al.*,2000, (11-22) minutes for tested rice varieties.

Elongation ratio: Shahidullah*et al.,* (2009) reported that higher elongation ratio of the cooked rice is preferred by the consumer than that with low elongation ratio.So, high elongation of rice cultivars during cooking is a preferable quality factor. Elongation of rice can be influenced by both L/B ratio and amylose contents (Singh *et al*., 2005 and Danbana*et al*., 2011). Some varieties show extreme elongation along the long axis on cooking. Grains elongate considerably more when cooked after presoaking compared with direct cooking. Elongation ratio of the total samples in this study varied from 1.5 to 2.3 among the rice cultivars including local cultivars and HYVs.The ranges of elongation ratio were (1.5-2.0), (1.5-2.2) and (1.8-2.3) in long, medium and short grain rice cultivars, respectively. The range of elongation ratio obtained in the present study washigher than the data reported by Biswas *et al.,* 2000, (1.3-1.7); Deepa, 2004, (1.2-1.8); Hasiba*et al.,*2006, (1.2-1.5);Shilpa*et al*., 2010,(1.0-1.6) and Diako*et al*., 2011, (1.45-1.48) for tested milled rice varieties.

Volume expansion ratio: High volume expansion after cooking is considered to be a good quality of rice. It influences many of the starch properties of rice (Juliano, 1979). Urban people prefer the varieties that expand more in lengthwise than in breadthwise (Choudhury, 1979).Volume expansion ratio of the total samples in this study varied from 3.1 to 4.3 among the rice cultivars including local cultivars and HYVs. The ranges of volume expansion ratio were (3.1-4.0), (3.1-4.3) and (3.4-4.0) in long, medium and short grain rice cultivars, respectively. The range of volume expansion ratio obtained in the present study washigher than that data reported by Biswas *et al.,*2000, (3.2-4.3) for tested milled rice varieties. Butthe range of volume expansion ratio obtained in the present study waslower than the data reported by Deepa, 2004, (3.4-4.7); Hasiba*et al.,* 2006, (3.0-4.3) and Shilpa*et al*., 2010, (2.0-4.23) for tested rice varieties.

Aroma: Aroma of scented rice is a major character which increases the value of rice in international market (Nayak*et al*., 2002). In India the famous aromatic rice is Basmati, which had a slender shape and long grain (Kamath *et al.,* 2008). The aromatic cultivars of rice in Bangladesh are usually cultivated in Aman season. Among them, some cultivars invariably possess a strong aroma. In this study, only 24cultivars were aroma but 105 cultivars were no aroma among long, medium and short grain rice cultivars including local cultivars and HYVs.So, few cultivars were aroma among the total tested rice cultivars. The finding of this study was similar to that finding reported by Shilpa*et al*., 2010; a small number of native varieties were aroma among the varieties.

Correlation of milling and cooking properties: The relationship among milling and cooking properties has been studied extensively.Hull content was highly significant and negatively correlated with milling outturn in long, medium and short grain rice cultivars. The finding of the present study was similar to that finding reported by Shobha*et al.,* 2003; a significant relationship had between hull weight and milling recovery (-0.88**, -0.58*). Head rice recovery was negatively correlated with milling outturn in long grain but positively correlate with milling outturn in both medium and short grain rice cultivars. For long grain rice cultivars, the finding of the present study was dissimilar but for medium and short grain rice cultivars,the finding of the present study was similar to that finding reported by Duttaa*et al*., 2013; head rice recovery was found to have a strong positive correlation (R2=0.818, $P<0.05$) with milling outturn. Alkali spreading value was significant and positively correlated with head rice recovery in long grain rice cultivars but it was negatively correlated with head rice recovery in both medium and short grain rice cultivars. For long grain rice cultivars, the finding of the present study was dissimilar but for medium and short grain rice cultivars, the finding of the present study was almost similar to that finding reported by Juliano*et al*., 1993; head rice recovery was significant and negatively correlated with alkali spreading value ($r= -0.16$, $p<0.05$).

Elongation ratio was highly significant and positively correlated with cooking time in long grain rice cultivars. The finding of the present study was almost similar to that finding reported by Oko*et al.,*2012; significantly positive correlation was observed between grain elongation and cooking time. Volume expansion ratio was significant and positively correlated with elongation ratio in long grain rice cultivars as well as only positively correlated with elongation ratio in medium and short grain rice cultivars. The finding of the present study was almost similar to that finding reported by Madan and Bhat, 1984; kernel elongation of rice was significant and positively correlated with volume expansion ratio.

Gelatinization temperaturehas inverse relationship with alkali spreading value. Alkali spreading value was highly significant and negatively correlated with cooking time in long grain rice cultivars as well as only significant and negatively correlated with cooking time in medium grain rice cultivars. The finding of the present study was almost similar to the finding reported by Juliano, 1967; gelatinization temperature and cooking time of milled rice was positively correlated; Oko*et al.,* 2012; significantly positive correlation was observed between gelatinization temperatures and cooking time as well asDuttaa*et al*., 2013;a negative correlation (R2= -0.245, P>0.05) was also found between alkali spreading value and cooking time. Alkali spreading value was highly significant and negatively correlated with volume expansion ratio in long grain rice cultivars.The finding of the present study was almost similar to that finding reported byFauziya*et al.,* 2015; alkali spreading value had negative correlation with volume expansion ratio. In medium and short grain rice cultivars alkali spreading value was positively correlated with elongation ratio. The finding of the present study was dissimilar to that finding reported by Madan and Bhat, 1984;kernel elongation ratio was found to be not related with alkali spreading value.

5.4 Mineral elements

Minerals play an important role in regulating physiological processes of the body. Rice varieties are good sources of minerals which can contribute to the recommended dietary allowance (Heinemann *et al.*, 2005). Watts, (1980) reported that the minerals composition of twelve samples of Canadian wild rice consisting of P, K, Mg, Fe, Mn, Zn and Cu. Similarly, Sotelo *et al*., (1990) analyzed twelve Mexican varieties of rice for 16 minerals composition. A similar study has been carried out by Phuong *et al.,* (1999) for Vietnamese rice. The minerals composition of K, Mg, Ca, Zn, Cu, Al, and Mn in Vietnamese rice were found to be in close agreement to those of Pakistani rice varieties both macro (Na, K, Mg and Ca) and micro (Zn, Fe, Cu, Al, Mn and Pb) minerals in ten selected rice varieties analyzed by Zubair, (2011). Likewise, Bennett, (1993) also analyzed minerals (K, Ca, Na, Mg, Fe, Zn, Cu, Al, Mn and Pb) in ten varieties of rice. Marr *et al.,* (1995) analyzed ninety samples of Australian brown rice for S, Mg, Ca, Na, Al, Cu, Fe, Mn, and Zn. Similarly, Yawen, (2009) analyzed minerals composition of P, K, Ca, Mg, Fe, Zn and Cu in Yunnan brown rice have rather high contents of nutritional elements. Different rice genotypes contain different contents of minerals (Sangha and Sachdeva, 1999). Variation of minerals composition may be due to varietal effects, diverse soil fertility and growth conditions in the various locations. It was already well documented that environmental conditions could greatly influence the contents of minerals elements in rice grains (Graham *et al.,* 2001).

Phosphorous: Phosphorus is the second most common mineral in the body. It is a building block for bones and teeth. It has been reported by many researchers that phosphorous deficiency has a significant influence on leaf photosynthesis and carbon metabolisms in plants (Rao, 1996).Phosphorous content of the total samples in this study varied from

0.17% to 0.43% among the rice cultivars including local cultivars and HYVs. The ranges of phosphorous content of brown rice was (0.19-0.43)% with mean 0.33±0.051%, (0.17-0.41)% with mean 0.30±0.066% and (0.23-0.39)% with mean 0.34±0.041% in long, medium and short grain rice cultivars respectively. The range of phosphorous content obtained in the present study was higher than the data reported by Watts, 1980, (0.28%); Adu-Kwarteng *et al*., 2003, (1.00-1.98) mg/g; Yawen, 2009, (3797.72 mg/kg) andDiako*et al*., 2011,(1166-1374) mg/kg for the tested local rice varieties.Local cultivars had higher phosphorous content than HYVs in respect of long, medium and short grain rice cultivars. The statement of the present study agreed with that data reported by Siddiquee, 2010, (3.0-3.9) mg/g for traditional varieties and (2.7-3.3) mg/g for HYVs of tested brown rice.

Calcium: Calcium is an essential element for living organisms. The body needs calcium for muscles to move and for nerves to carry messages between the brain and every body part. In humans, calcium is the most abundant mineral and forms about 2% of our total body weight. Almost all of this calcium is found in the skeleton. In plants, calcium-dependent protein kinases are involved in tolerance to abiotic stresses and in plant seed development. Calcium content of the total samples in this study varied from 0.01% to 0.06% among the rice cultivars including local cultivars and HYVs. The ranges of calcium content of brown rice were (0.01-0.06)% with mean 0.03±0.010%, (0.02-0.06)% with mean 0.04±0.011%and (0.01-0.06)% with mean 0.03±0.012% in long, medium and short grain rice cultivars respectively. The range of calcium content obtained in the present study was higher than the data reported by Doesthale*et al*., 1979, (180.0 μg/g); Phuong *et al*., 1999,(37-212) mg/kg; Adu-Kwarteng *et al*., 2003, (241.1 μg/g) and Yawen, 2009, 155.90 mg/kgfor tested rice cultivars.

But the range of calcium content obtained in the present study was lower than the data reported by Kennedy and Burlingame, 2003, (10-650) μg/g as well as Zubair,2011, (825-1330) mg/kg for tested rice cultivars.Local cultivars had lower calcium content than HYVs in respect of long, medium and short grain rice cultivars. The statement of the present study disagreed with that data reported by Siddiquee, 2010, (118.1-177.8) μg/g for traditional varieties and (117.8-162.7)μg/g for HYVs of tested brown rice cultivars. The variation may be due to varietal effects, inherent capacity to accumulate calcium from diverse soil fertility and growth conditions with varying agronomic practices in the cultivation of rice (Combs, 1988).

Magnesium: Although rice has the lowest magnesium content among the cereal crops butmagnesium is an important micro nutrientbecause,it is needed for many biochemical reactions in living organism. It has an important role in photosynthesis for plant as well as nerve impulse conduction, muscle contraction and normal heart rhythm for animal. Magnesium content of the total samples in this study varied from 0.10% to 0.14% among the rice cultivars including local cultivars and HYVs. The ranges of magnesium content of brown rice were (0.10-0.14)% with mean 0.12±0.012%, (0.10-0.13)% with mean 0.12±0.009%and (0.10-0.14)% with mean 0.12±0.010% in long, medium and short grain rice cultivars respectively. The range of magnesium content obtained in the present study was higher than the data reported by Watts, 1980, (0.11%) for Canadian rice and Zubair, 2011, (960-1235) mg/kg for rice cultivars. But the range of magnesium content obtained in the present study was lower than the data reported by Phuong *et al*., 1999, (137-1456) mg/kg for Vietnamese riceand Yawen, 2009, 1512.86 mg/kg for Yunnan brown rice.

Nitrogen: Nitrogen is an essential nutrient for living body being a component of amino acids, nucleic acids, nucleotides, chlorophyll, enzymes and hormones. It promotes rapid plant growth, improves grain yield and grain quality through higher tillering, leaf area development, grain formation, grain filling and protein synthesis. Nitrogen is highly mobile within the plant and soil. Murayama (1973) reported that the rice plant must absorb larger amount of nitrogen to produce higher grain yield. Nitrogen content of the total samples in this study varied from 1.1% to 1.8% among the rice cultivars including local cultivars and HYVs. The ranges of nitrogen content of brown rice were (1.1-1.7)%with mean 1.4±0.136%, (1.1-1.8)% with mean 1.4±0.146%and (1.2-1.6)% with mean 1.4±0.109%in long, medium and short grain rice cultivars respectively. The range of nitrogen content obtained in the present study washigher than that data reported by Graeme and Batten, 2002, (10320-12126) mg/kg with mean value of 11540 mg/kg for brown rice. Earlier literatures indicated that varieties differing in plant type markedly differ in their response to add nitrogen levels (Evatt*et al*, 1960 and Tanaka *et al*, 1964a).

Potassium: Potassium is an essential nutrient that affects most of the biochemical and physiological processes that influence plant growth and metabolism. Potassium deficiency damage is important throughout the growth cycle of plant. Potassium helps to the survival of plants exposed to various biotic (e.g., pathogens, insects and weeds) and abiotic (e.g., drought, salinity, cold, frost and water-logging) stresses. So, potassium can minimize the drought effects of rice.Potassium content of the total samples in this study varied from

0.13% to 0.30% among the rice cultivars including local cultivars and HYVs. The ranges of potassium content of brown rice were (0.15-0.26)% with mean 0.20±0.026%, (0.13-0.30)% with mean 0.21±0.035%and (0.16-0.30)% with mean 0.22±0.039%in long, medium and short grain rice cultivars respectively. The range of potassium content obtained in the present study was higher than that data reported by Zubair, 2011, (2378-2794) mg/kg for rice cultivars.But the range of potassium content obtained in the present study was lower than the data reported by Watts,1980, 0.30% for Canadian rice; Phuong *et al*., 1999,(497-2833) mg/kg for Vietnamese rice and Yawen, 2009, 2631.70 mg/kg for Yunnan brown rice.

Sodium: Sodium is an essential nutrient that regulates blood volume, blood pressure, osmotic equilibrium and pH but becomes harmful for body at high level. On the other hand, sodium aids chlorophyll synthesis for plant. In general, rice plant shows variability in its sensitivity to excessive salinity at different stages of growth. The vegetative and early reproductive stages are the most sensitive to salinity which directly affects the yield.Sodium content of the total samples in this study varied from 125 ppm to 332 ppm among the rice cultivars including local cultivars and HYVs. The ranges of sodium content of brown rice were (126-297) ppm with mean 264±41.3 ppm, (125-321) ppm with mean 252±58.5 ppm and (126-332) ppm with mean 256±56.8 ppmin long, medium and short grain rice cultivars respectively. The range of sodium content obtained in the present study was higher than the data reported by Siscar-Lee *et al*., 1990, (19-37) ppm;Nadia, *et al*., 2009, (129-170)mg/kg and Zubair, 2011, (89-109) mg/kg for rice cultivars.

Iron: Rice is the cereal crop, which in general is not rich in iron stated by Welch and Graham, (2000). Additionally, Graham *et al*., (2000) reported that rice is inherently low in iron and milling removes half or more of that, hence making rice the poorest of all the cereals in iron. But iron is one of the most important micronutrients in the human diets. The deficiency of iron caused anemia affecting a healthy life development (Hoa and Lan, 2004). On the other hand, iron deficiency causes chlorosis symptoms in rice plant. So iron content in rice is influenced by nitrogen application and soil quality (Senadhira*et al*., 1998). Iron content of the total samples in this study varied from 6 ppm to 10 ppm among the rice cultivars including local cultivars and HYVs.The ranges of iron content of brown rice were(6-10) ppmwith mean 8±1.10 ppm, (6-10) ppm with mean 8±1.06 ppmand (7-10) ppm with mean 8±1.03ppm in long, medium and short grain rice cultivars respectively. The range of iron content obtained in the present study was higher than the data reported by

Graham *et al*., 1998, (22.2-22.9) µg/g with high value and Diako*et al*., 2011, (5.0-8.2) mg/kg for rice cultivars.

But the range of iron content obtained in the present study was lower than the data reported by Watts, 1980, (17 ppm); Graham *et al*., 2000, (7.5-24.2) µg/g; Kennedy and Burlingame, 2003, (7.0-63.5) µg/g;Hoa*et al*., 2004, (12.4 µg/g); Yawen, 2009, (32.56) mg/kg as well as Zubair, 2011, (186-317) mg/kg for rice cultivars. Local cultivars had higher iron content than HYVs in respect of long, medium and short grain rice cultivars. The statement of the present study agreed with the statement reported by Graham *et al*., 2000; some traditional rice varieties was 2.5 times more iron content than commonly grown high yielding counterpartsas well asSiddiquee, 2010; the range of iron content was (13.9-21.6) µg/g with mean17.3 µg/g in brown rice of traditional varieties and (11.9-17.7) µg/g with mean 15.5 µg/g in brown rice ofHYVs.

Zinc: Zinc is an essential nutrient for living body. It requires for several biochemical processes in plant such as chlorophyll production. Zinc limits plant growth when the soil supply of zinc is low or adverse soil conditions (such as continuous flooding) prevent plant uptake of zinc. Effect of zinc may develop brown spot on rice. Brown spot is one of the most destructive diseases of rice. It is capable of reducing rice grain yield up to 80%. Zinc content of the total samples in this study varied from 10 ppm to 20 ppm among the rice cultivars including local cultivars and HYVs. The ranges of zinc content of brown rice were(10-20) ppmwith mean 16±2.77 ppm, (10-20) ppm with mean 16±2.86 ppmand (11-20) ppm with mean 16±2.40 ppm in long, medium and short grain rice cultivars, respectively. The range of zinc content obtainedin the present study was higher than that data reported bySiddiquee, 2010, (12.9-19.3) µg/g in HYVs of brown rice.But the range of zinc content obtained in the present study was lower than the data reported by Watts, 1980,(51 ppm);Phuong *et al*., 1999, (15-30) mg/kg; Graham *et al*., 1999, (15.9-58.4) µg/g; Kennedy and Burlingame, 2003, (7.9-58.9) µg/g; Yawen, 2009, 32.49 mg/kg; Siddiquee, 2010, (17.2-29.8) µg/gas well as Zubair, 2011, (191-319) mg/kg zinc content for rice cultivars. In this study, medium grain local rice cultivars had higher zinc content than HYVs. The statement of the present study agreed with that statement reported by Siddiquee, 2010;the majority of traditional varieties had higher zinc content compared to those of HYVs.

Correlation of mineral elements: The relationship among mineral elements has been studied extensively.Calcium content was significant and negatively correlated with phosphorous content in medium grain rice cultivars as well as it was only negatively correlated with phosphorous content in long and short grain rice cultivars. The finding of the present study disagreed with that finding reported bySiddiquee, 2010; phosphorous content was significant and positively correlated with calcium content.

Potassium content was positively correlated with magnesium content in long grain rice cultivars; it was highly significant and positively correlated with magnesium content in medium grain rice cultivars as well as it was significant and positively correlated with magnesium content in short grain rice cultivars. The finding of the present study agreed with that finding reported by Marr *et al*., 1995; highly significant positive correlations were found between the levels of potassium and magnesium of rice varieties.

Magnesium content was highly significant and negatively correlated with calcium content in long grain rice cultivars as well as it was only negatively correlated with calcium content in medium and short grain rice cultivars. The finding of the present study disagreed with that finding reported by Jiang *et al*., 2007; magnesium content was significantly correlated with calcium content.

Sodium content was positively correlated with calcium content in long grain rice cultivars but it was significant and negatively correlated with calcium content in short grain rice cultivars. The finding of the present study disagreed with that finding reported by Oko and Ugwu, 2011; no significant difference exists in sodium and calcium contents of the rice varieties studied.

Nitrogen content was highly significant and positively correlated with potassium content in medium grain rice cultivars as well as it was significant and positively correlated with potassium content in short grain rice cultivars. The finding of the present study agreed with that finding reported by Oko and Ugwu, 2011; there was significant difference in nitrogen and potassium.

Zinc content was significant and positively correlated with iron content in long and medium grain rice cultivars as well as it was only positively correlated with iron content in short grain rice cultivars. The finding of the present study agreed with the finding reported by Anjum*et al*., 2007; mineral contents (Fe and Zn) of four Pakistani rice varieties to be varied significantly; Jiang *et al*., 2007; iron content was significantly correlated with zinc content as well asSiddiquee, 2010; zinc content was significant and positively correlated with iron content.

5.5 Nutritional quality

The nutritional situation in rice consuming countries varies substantially depending on a web of interacting socio-economic, cultural, developmental, environmental and dietary factors. The knowledge of the proximate composition (carbohydrate, protein, fat, ash, crude fiber and moisture) of cereals being essential ingredients for human diet is much important, especially when determining their functional food applications. Such compositional data provide an understanding about the factors that establish the properties of grains to ensure it safe, nutritious and desirable for consumers from dietary perspectives (Abdulaziz and Bahrany, 2002).

Rice is a complex carbohydrate. Complex carbohydrates are digested slowly, allowing the body to utilize the energy released over a longer period which is nutritionally efficient. Oil content of milled rice also improves its energy value. The ash content of a food sample gives an idea about the mineral elements present in that food sample. Dietary fiber as a food substance has increased dramatically over past years. The moisture content is considered as an important feature because all grains are stored for a certain period before their ultimate utility. Protein is the second highest component of rice. The nutritional value depends on the total quantity and quality of protein in the rice grain. Proteins from various tissues of the rice grain and grains in the same variety differing in protein content may be explained in part by differences in the ratio of the protein solubility fractions according to Osborne (1907). Amino acids are building blocks of proteins. Cereals show great variations in the amounts of amino acids, largely depending on the species, cultivar and growing conditions (Abdel-Aal and Hucl, 2002). The advantage of protein from rice is highly digestible, non-allergic and may be the only protein source with hypoallergenic. Rice starch is considered easily digestible than other cereal starches. Furthermore, raw rice starch is relatively easily digestible (Casiraghi *et al.*, 1993).

Carbohydrate content: Rice is considered as complex carbohydrate because it is primarily comprised of long-chain polymers. Carbohydrate provides fuel to do everything. In fact, it is so essential that it provides the lion's share of the calories in a balanced diet. Rice varieties differ widely on the basis of carbohydrate content. Carbohydrate content of the 18 selected samples in this study varied from 71.18% to 75.07% among the local rice cultivars. The range of carbohydrate content obtained in the present study was almost similar to that data reported by Abdulaziz and Bahrany, 2002, (72-75)%carbohydratecontentfor two different varieties of Saudi rice. The range of carbohydrate content obtained in the present study was higher than that data reported by Zakir and Biswas, 2009; carbohydrate content of the rice samples varied from 78.93% to 80.59% with higher values. But the range of carbohydrate content obtained in the present study was lower than the data reported by Zhai*et al.*, 2001 and Liu *et al.*,2008; the range of carbohydrate content was (70-75)%. Overall, the tested rice cultivars in the present research work were found to have appropriate amount of carbohydrates for dietary purpose.

Fat content: Cereals being a reasonable source of food lipids contribute to provide energy for the human body. The amount of fat freely present on the surface of the rice grain initially increases until about 4% degree of milling (by weight) and then decreases as the surface layers are removed (Bhattacharya *et al*., 1972). Fat content in different milling fractions varied from 0.9% to 1.97% (Juliano, 1985b).Fat content of the 18 selected samples in this study varied from 2.56% to 3.61% among the local rice cultivars.The range of fat content obtained in the present study was higher than the data reported by Abdulaziz and Bahrany, 2002,(2.02-2.29) g/100g; Liu *et al.*, 2008,(2.8-3.3) g/100g as well as Zubair, 2011, (1.92-2.72) g/100g fat content of rice. But the range of fat content obtained in the present study was lower than the data reported by Oko and Ugwu, 2011, (0.5-3.5)% and Rachel *et al*., 2013, (0.07-1.74)% fat content of ricewith lower values.

Ash content: The ash content is an indicator of the total quantity of minerals in plant materials. Ash content of polished samples decreased from 1.2% to 0.64% at 11.35% degree of polished rice (Veena*et al*., 1999). Ash content of the 18 selected samples in this study varied from 1.02% to 1.38% with mean of 1.2% among the local rice cultivars.The range of ash content obtained in the present study was higher than the data reported by Awan, 1996; the ash content in some varieties varied from (0.5-0.82)% and Biswas, 2009; the range of ash content was (0.29-0.52)%. The mean value of ash content obtained in the present study was similar to the data reported by Doesthale*et al*., (1979) and Chun-Ying *et al.*,(2008), the value of ash content was 1.2%. But the range of ash content obtained in the present study was lower than the data reported by Juliano and Bechtel, 1985, (0.3-0.8)% with low value; Sotelo *et al*., 1990, (1.4-1.9)%; Singh *et al*., 1999, (0.74-1.36)%; Siddiquee, 2010, (0.4-0.9)% with low valueas well as Zubair, 2011, (1.48-1.98) g/100g ash content for rice varieties. Such variation in the results of ash contents for rice with those of available literature can be linked to rice cultivars as well as agro-climatic conditions of the harvest.

Crude fiber content: Crude fiber is new addition in our nutritional quality. It remains an important constituent of food, yet it cannot be considered as an essential nutrient. Although, rice is not a significant source of dietary fiber but it alters the digestibility as well as affects the digestion process. The rice rich in crude fiber enhance the functions of digestive system and also reduce the risk of intestinal disorders.Crude fiber content of the 18 selected samples in this study varied from 0.61% to 0.99% with mean of 0.8% among the local rice cultivars.The range of crude fiber content obtained in the present study was higher than that data reported by Tufail, 1997; the crude fiber content varied from 0.20% to 0.35% in different Pakistani rice varieties. But the range of crude fiber content obtained in the present study was lower than the data reported by Sotelo *et al*., 1990; the mean value of crude fiber content was 1.9%;Edeogu*et al*., 2007;the range of crude fiber content was (1.93-4.3)% as well asOko and Ugwu, 2011;the range of crude fiber content was (1.5-2.0)%. Minor differences for the crude fiber contents among tested rice varieties of this present study were recorded. The differences in the crude fiber content may be attributed on the basis of post-harvest processing techniques.

Moisture content: Moisture content is one of the most important properties of rice that is important for several technical and commercial applications. In several ways, moisture content affects rice quality. To gain and maintain the optimum milling quality, rice must be harvested at proper moisture content and should be dried carefully up to 14%. Moisture content of the 18 selected samples in this study varied from 12.3% to 13.4% among the local rice cultivars.The range of moisture content obtained in the present study was higher than the data reported byZhai*et al.,* 2001, (9.12-9.54)%;Abdulaziz and Bahrany, 2002, (8.83-9.20)% as well as Zakir and Biswas, 2009, (11.62-12.45)% moisture content of rice. But the range of moisture content obtained in the present study was lower than the data reported by Zubair, 2011,(6.84-9.02)% and Rachel *et al*., 2013, (10.04-12.88)% moisture content of rice cultivars with low value.

Protein content: Twenty percent of the human body is made up of protein. Protein is an important constituent of plant foods. Growing group of scientists who feel that protein plays a substantial role in varietal difference of rice. Protein is the second highest component of rice. So, rice is the main source of protein for most of the rice consuming people reported by Mitra and Das, (1971) as well as Gomez, (1979). It supplies 55% of the total protein consumed in Bangladesh reported by Bhuiyan*et al*., (2002). Aleuronic and sub-aleuronic parts of rice kernel are rich in protein. Protein content of the total samples in this study varied from 6.5% to 10.7% among the rice cultivars including local cultivars and HYVs.The ranges of protein content of brown rice were (6.5-10.5)%, (6.5-10.7)% and (7.2-9.7)% in long, medium and short grain rice cultivarsrespectively.The range of protein content obtained in the present study was almost similar to that data reported byAdu-Kwarteng *et al.*, 2003;the range of protein content forrice varieties was (5.95-10.50)%. The range of protein content obtained in the present study was higher than the data reported by Perdon and Juliano, 1978, (8.2-12.1)%; Pinciroli*et al.*, 2008, (8.65-9.56) g/100g; Zubair, 2011, (7.5-9.16) g/100g as well asRachel *et al*., 2013, (5.96-8.16)%protein content for the rice varieties. But the range of protein content obtained in the present study was lower than the data reported byJuliano, 1968, (5-17)%;Juliano, 1972,(6-13)% as well as Villareal and Juliano, 1978, (5.9-11.9)% protein content for the rice varieties. The large variation in protein content was observed between plants and within the same plants (Juliano, 1972).

In this study, milled rice protein was highly significant and positively correlated with brown rice protein ($r=0.997$, $p<0.01$). The finding of the present study was almost similar to the finding reported by Juliano*et al.*,1964b; the protein content of brown and milled rice were significantly correlated (r= 0.96**, n=55); Juliano*et al*., 1973 and Ellis *et al*., 1986; linear positive correlation between brown rice protein content and milled rice protein content among different varieties of rice was similar.

Milling effect on protein: Milling decreases milled rice protein content reported by Yoshizawa and Ogawa, (2004). This is attributed to the removal of rice kernel's outer most layers that are known to be rich in protein (Saleh and Meullenet, 2013). The ranges of protein content for15 selected samples in this study were (7.0-10.7)%in brown and (6.2-9.6)% in milled rice cultivars. Due to milling the range of protein loss for these selected rice cultivars was (8.6-14.3)%. The range of protein loss in the present study was higher than that data reported by Saleh and Meullenet, 2013; the protein loss of 2 rice varieties due to milling was 5.5% and 6.9%. The range of protein loss in the present study was lower than the data reported by Muhammad *et al*., 2002; the protein loss due to milling was 21%;Siddiquee, 2010;the range of protein loss due to milling was (7.2-29.3)% in traditional varieties of rice and Abbas *et al*., 2011;protein loss for rice varieties was 29%.

Milled rice of Depa had the highest protein loss (14.5%) with lower milled rice protein (6.5%) and Boradudhkalam had higher protein loss (13.3%) with lower milled rice protein (6.5%) but Neda had the lowest protein loss (8.6%) with highest milled rice protein (9.6%) and Boylam had lower protein loss (8.8%) with higher milled rice protein (9.3%) after milling among the selected local rice cultivars.So, cultivars with higher brown and milled rice protein has shownthe lower milling loss of protein in this study. The finding of the present study agreed with that finding reported by Resurreccion*et al*., 1979; the loss of protein from milling was greater for low protein rice than for high protein rice.

Cookingeffect on protein: Protein depletion occurs in rice varieties during cooking reported by Osaretin*et al*., (2007). This loss of protein may be due to protein denaturation, anti-nutritive factors and leaching effects of water. Moreover, the protein content of rice, while limited (ranging from 2.0 to 2.5 mgper 1/2 cup of cooked rice), is considered one of the highest quality proteins among that provided by other cereal grains. The ranges of protein content for 15 selected samples in this study were (6.2-9.6)% in milled and (5.74-8.83)% in cooked rice cultivars. Due to cooking the range of protein loss for these selected rice cultivars was (4.0-20.0)%. The data of protein loss in the present study agreed with the statement reported by Singh *et al*., 1998; Azhakanandam*et al*., 2000 and Park *et al*., 2001; during cooking of rice, especially in excess water disproportionate losses of protein component. But the range of protein loss in the present study washigher with lower value than that data reported by Osaretin*et al*., 2007; the rice cultivars of Ofadawas 42.60% and Arosowas 49.64% protein loss due to cooking.

Fractionation of protein: Osborne (1907) classified plant proteins based on the protein solubility. Rice varieties differ widely on the basis of fractionation ofprotein. The ranges of fractionation ofproteinfor 10 selected samples in this study were (7.3-12.2) g/100g of albumin, (4.6-6.7) g/100g of globulin, (4.0-4.9) g/100g of prolamin and (78.0-82.8) g/100g of glutelin.The range of albumin obtained in the present study was higher than the data reported by Simmonds, 1978, (2-5)% albuminas well asLanders and Hamaker, 1994, (9-11)%albumin for rice kernel.The ranges of globulin and prolaminobtained in the present study was lower than the data reported by Simmonds, 1978,(2-10)% globulin and (1-5)% prolaminas well asLanders and Hamaker, 1994, (7-15)% globulin and (2-4)%prolamin for rice kernel. The range of glutelinobtained in the present study wasalso lower than that data reported by Simmonds, 1978, (75-90)%glutelin for rice grain.

The ratio (mean values) of fractionation ofproteinsuch as albumin, globulin, prolamin and glutelin for 10 seelectedsamplesin this study was 9.9:5.4:4.5:80.1. The mean value of albumin obtained in the present study was higher than the data reported by Mitra and Das, 1975,(9%) as well as Padhye and Salunkhe, 1979, (8%) for albumin. But the mean value of albumin obtained in the present study was lower than the data reported by Chavan and

Duggal, 1978 as well as Wieser*et al*., 1980a, (11%) for albumin. The mean value of globulin obtained in the present study was lower than the data reported by Mitra and Das, 1975, (7%);Chavan and Duggal, 1978, (15%); Padhye and Salunkhe, 1979, (10%) as well as Wieser*et al*., 1980a, (10%) for globulin. The mean value of prolaminobtained in the present study was higher than the data reported byMitra and Das, 1975, (4%); Chavan and Duggal, 1978,(3%)as well as Wieser*et al*., 1980a, (2%) for prolamin. But the mean value of prolaminobtained in the present study was lower than that data reported by Padhye and Salunkhe, 1979, (12%) for prolamin.The mean value of glutelinobtained in the present study was higher than the data reported by Chavan and Duggal, 1978, (71%);Padhye and Salunkhe, 1979, (70%)as well as Wieser*et al*., 1980a, (77%) for glutelin. But the mean value of glutelinobtained in the present study was almost similar to that data reported by Mitra and Das, 1975as well as Landers and Hamaker, 1994, (80%) for glutelin of rice grain.

In this study, the richest range of glutelinwas (78.0-82.8) g/100g but the lowest range of prolaminwas (4.0-4.9) g/100g among the selected samples. The finding of the present study was similar to the finding reported by Simmonds, 1978as well as Payne and Rhodes, 1982; rice protein is unique among the cereal proteins due to the richest in glutelin and the lowest in prolamin. Albumin was significant and positively correlated with protein content ($r=0.744$, $p<0.05$) in this study. The finding of the present study was almost similar to that finding reported by Chavan and Duggal, 1978; the albumin content increased with protein content among the four improved rice varieties. But the finding of the present study was dissimilar to that finding reported by Villareal and Juliano, 1978;glutelin and protein contents were positively correlated ($r = 0.96^{**}$).

Amino acid composition: Amino acids are important because they are considered to be the building blocks of proteins.Protein plays a crucial role in almost all biological processes.Amino acid composition varies in different fractions of rice kernel. In this study, 9 rice cultivars were selected for amino acid composition. The ranges of amino acid composition were(7.76-10.49) g/100g arginine, (3.34-4.29) g/100g lysine, (5.24-5.79) g/100g alanine, (3.34-3.97) g/100g threonine, (4.51-4.80) g/100g glycine, (5.10-7.25) g/100g valine, (4.69-5.74) g/100g serine, (4.73-5.11) g/100g proline, (4.33) g/100g isoleucine, (7.94-8.21) g/100g leucine, (2.09-2.23) g/100g methionine, (2.23-2.61) g/100g histidine, (4.93-5.32) g/100g phenylalanine, (17.39-18.30) g/100g glutamate, (8.74-9.50) g/100g aspartate, (1.36-2.40) g/100g cystineand (4.44-5.83) g/100g tyrosine.

The ranges of arginine, lysine, threonine and tyrosine in this study were higher than the data reported by Houston *et al*., 1969; Kennedy and Schelstraete, 1974 as well asJuliano and Bechtel, 1985, (8.5-10.5)% arginine, (3.9; 4.3)% lysine, (3.9-4.0)% threonine and (3.8-4.6)% tyrosine;Kaul*et al*., 1982, (7.69-8.29)% arginine, (3.13-3.81)% lysine, (2.95-3.42)% threonine and (4.44-5.52)% tyrosine as well asZubair, 2011, (0.46-0.86) g/100g arginine, (0.22-0.37) g/100g lysine, (0.21-0.32) g/100g threonine and (0.14-0.33) g/100g tyrosine.

The range ofcystinein this study was higher than the data reported by Houston *et al*., 1969; Kennedy and Schelstraete, 1974as well asJuliano and Bechtel, 1985,(2.2-2.4)% cysteine and Kaul*et al*., 1982,(1.31-2.16)% cystine.

The ranges of aspartate, histidine, alanine, valine and serine in this study were higher than the data reported byKaul*et al*., 1982, (8.51-9.12)% aspartate, (2.2-2.35)% histidine, (5.2-5.58)% alanine, (5.2-5.56)% valine and (4.61-4.78)% serine as well asZubair, 2011, (0.46-0.75) g/100g aspartic acid, (0.09-0.21) g/100g histidine, (0.30-0.53) g/100g alanine, (0.25-0.48) g/100g valine and (0.20-0.47) g/100g serine. But in this study, the range of valine was lower and the range of serine was almost similar to the data reported by Houston *et al*., 1969; Kennedy and Schelstraete, 1974 as well as Juliano and Bechtel, 1985, (4.8-7.4)%valine and (4.8-5.8)%serine.

The range of glycine in this study was lower than the data reported byKaul*et al*., 1982,(4.03-4.39)% glycine and Zubair, 2011, (0.19-0.51) g/100g glycine.

The ranges of methionine, phenylalanine and glutamate in this study were higher than that data reported byZubair, 2011, (0.17-0.26) g/100g methionine, (0.29-0.43) g/100g phenylalanine and (0.91-1.51) g/100g glutamic acid. But the ranges of methionine, phenylalanine and glutamate in this study were lower than that data reported byKaul*et al*., 1982, (1.55-2.55)% methionine, (4.91-5.36)% phenylalanine and (17.09-18.27)% glutamate.

In this study, higher lysine waspresent in Magoibalam, Motichak and Boylamat high level of protein content among the selected samples. The finding of the present study was similar to the finding reported by Kaul*et al*., 1978; some varieties retained higher lysine content at high protein levels of four Bangladeshi rice varieties as well as Chavan and Duggal, 1978; four new improved rice varieties developed in India were found to have high levels of lysine at high protein content rice cultivars. Moreover, glutamate was high among the amino acid composition for nine selected rice samples. The finding of the present study was similar to the finding reported by Juliano, 1993 andZubair, 2011;glutamic acid was high among the amino acid profile of rice.

In this study, protein was highly significant and positively correlated with lysine ($r=0.882$, $p<0.01$). The finding of the present study was similar to that finding reported by Chavan and Duggal, 1978;lysine content per unit of brown rice was found to increase with an increase in the protein content of Indian rice varieties. But the finding of the present study was dissimilar to that finding reported byJuliano*et al*., 1968; lysine level in the protein and the protein content were negatively correlated. Later, the finding of the present study was partly similar and partly dissimilar to that finding reported by Siddique, 2010; lysine content of rice increased with an increased in protein content in some HYVs of rice whereas lysine content decreased with an increase in the protein content in other HYVs of rice.

Protein digestibility: Protein value in human body is measure by the protein digestibility. So, protein quality is evaluated by protein digestibility. Protein digestibility is the amount of protein absorbed into the body relative to the amount that was consumed. Rice protein is highly digestible. Cooking may destroy the anti-nutritional factors present in rice and render rice protein more digestible. In vitro protein digestibility of the 15 selected samples in this study varied from 59% to 78% with the mean value of 65.26±5.06% among the local rice cultivars.The range of in vitro protein digestibility obtained in the present study was higher with low value than that data reported by Zakir and Biswas, 2009; the range of in vitro protein digestibility of rice was (88.3-98.4)% with high value. The mean value of the present study was higher than that data reported byKaul*et al*., 1982;the protein digestibility of rice was 58%. The data of the present study was almost similar to the data reported by Boisen*et al*., 2001; Tanaka (unpublished data) observed a higher in vitro pepsin digestibility of protein was (68%, 69% and 78%) in indica rice as well as National Research Council, 1989;the in vitro protein digestibility of rice was 76%. The increased in vitro protein digestibility of rice may be attributed to the inactivation of protease inhibitors, presence of lower amount of prolamin in rice protein and the opening up of the protein structure through denature.In vitro protein digestibility increases appreciably due to reduction in anti-nutrient contents after germination.

Starch digestibility: Starch is the major component of rice constituting about 90% of its dry matter reported by Patindol*et al*., (2009). Amylose content of starch influences the starch digestibility.Rice varieties with similar high amylose content can differ in gelatinization properties and this can also influence starch digestibility reported by Juliano,

(1984) and Panlasigui*et al*., (1991). In vitro starch digestibility of the 15 selected samples in this study varied from 62.31% to 83.79% at 120 minutes with the mean value of 72.46±7.58% among the local rice cultivars.The range of in vitro starch digestibility of the present study was higher than the data reported by Madhu*et al*., 2007, (73-86)% as well as Zakir and Biswas, 2009,(70.2-86.4)% in vitro starch digestibility of rice. The mean value of in vitro starch digestibilityof the present study was lower than that data reported by Patricia *et al*., 2002, (80.59%)digestible starch of whole rice. The starch digestibility of rice is affected overall by the degree of gelatinization during cooking, the granule particle size, the amylose/amylopectin ratio, starch protein interaction, amylose/lipid complexes and the level of resistant starch.In vitro starch digestibility increases appreciably due to reduction in anti-nutrient contents after germination.

5.6 Genetic diversity of *Waxy* gene

Amylose content: Amylose content is one of the most important traits that govern the eating, cooking and processing quality of rice as well as ultimately determines its market price.Amylose content of the total samples in this study varied from 5.0% to 29% among the rice cultivars including local cultivars and HYVs. The range of amylose content obtained in this study was higher than the data reported by Borua*et al.,* 2004, (19.7-20.9)%; Deepa, 2004, (23.6-29.4)%; Yadav *et al.,*2007, (2.25-22.21)%;Thongbam*et al.,* 2010, (14.33-29.47)% and Shilpa*et al.,* 2010, (17.86-24.75)% amylose content.

Amylose content of total long grain rice samplesin this study varied from 5.0% to 29.0%. The range of amylose content obtained in the present study was higher than the data reported by Lestaria*et al.,* 2011, (17.1-26.3)% and Diako*et al.,* 2011, (15.9-20.2)% amylose content for long grain rice cultivars. Amylose content of total medium grain rice samples in this study varied from 5.2% to 29.0%. The range of amylose content obtained in the present study was higher than that data reported by Lestaria*et al.,*2011, (17.0-23.4)%amylose content for medium grain rice cultivars. Amylose content of total short grain rice samplesin this study varied from 20.0% to 27.0%. The range of amylose content obtained in this study was higher than that data reported by Biswas *et al.,*2000, (21.6-27.4)%amylose content for short grain rice cultivars.

In this study amylose content of rice cultivars had positive correlation (r =0.23) with milled rice length. The finding of the present study was similar to the data reported by Fasahat*et al.,* 2012;amylose contentof rice cultivarshad positive correlation (r =0.018)with grain lengthand Thongbam*et al.,* 2012;amylose contentof rice cultivarshad positive correlation (r =0.186)with grain length.But the finding of the present study was dissimilar to that finding reported by Vanaja and Babu, 2003; negative significant correlation between length and amylose content of rice cultivars.

Microsatellite and cleaved amplified polymorphic sequence markers: Previous molecular genetic studies reported that the rice *Waxy* gene is multi-allelic which has been identified through allelic analysis by using polymorphisms of (CT)n repeat and the presence of G/T sequence. The RM190 microsatellite (CT)n alleles in the *Waxy* gene were first identified by Bligh *et al.,* (1995). Used microsatellite marker for (CT)n class was subsequently renamed RM190 (Temnykh*et al*., 2000). The amplified PCR products by using microsatellite RM190 ranged from 102bp to 128bp in length and represented the (CT)n repeat of $(CT)_7$ to $(CT)_{20}$ (Rahemi*et al*., 2007).

Four classes of allele having the 100bp, 110bp, 116bp and 120bp have been shown in this study using similar microsatellite RM190. The amplified PCR products of this study had 100bp, 110bp, 116bp and120bp which could similarly represent the $(CT)_6$, $(CT)_{11}$, $(CT)_{14}$ and $(CT)_{16}$repeat. Most of the $(CT)_6$ with the highest and$(CT)_{11}$ with the 2nd highest amount were found in the high amylose group; Equal amount with the lowest $(CT)_{14}$ was found in the high, intermediate and very low amylose group and most of the $(CT)_{16}$ was found in the intermediate and very low amylose group. The $(CT)_{11}$repeat except $(CT)_6$repeat for high amylose group of this study had similar to the $(CT)_{11}$ repeat for high amylose group of those data reported by Ayres *et al.,* (1997); Bergman *et al.,* (2001) and Prathepa, (2003).

The analysis of (CT)n alleles of the *Wx* gene in relation to the amylose contents has clearly shown that the alleles with fewer repeats were highly associated with higher apparent amylose content (AAC) and those with more repeats were highly associated with lower AAC in the previous studies (Ayres *et al.,* 1997).The CT repeat classes with repeat number 10 or 11, 14 or 20 and 17 or 18 were categorized as high amylose, intermediate amylose and low amylose types, respectively (Bergman *et al*., 2001). The microsatellite class $(CT)_{11}$ is associated with high amylose strains, whereas the two microsatellite classes, $(CT)_{17}$ and $(CT)_{18}$, were predominantly found among low amylose and glutinous strains in Thai germplasams (Prathepa, 2003).

Results have been shown in this study, out of 35 Bangladeshi rice cultivars a single nucleotide polymorphism (SNP) discriminated very low (<11%) amylose content cultivars

(AGTTATA sequence) from low, intermediate and high amylose content cultivars (AGGTATA sequence) by using (RM190F-GBSSW2R/*AccI*). The finding of this study had dissimilar to those findings reported by Ayres *et al.,* (1997) and Biselli*et al.,* (2014). Out of 89 non-glutinous USA rice cultivars, a single nucleotide polymorphism discriminated low (18% or less amylose) AAC-type cultivars (AGTTATA sequence) from intermediate and high AAC-type cultivars (AGGTATA sequence) (Ayres *et al.,* 1997). The available molecular markers haplotypes did not provide tools for predicting accessions with AAC higher than 24.5% (Biselli*et al.,* 2014).

5.7 Hybridization

The hybridization program in rice by making crosses between introduced and local varieties to combine together the desirable characteristics into superior type was initiated in early 1950's (Weeraratne, 1954). The protein content of rice differs according to the variety grown and is affected by growing conditions such as early and late maturing, soil fertility and water stress as well as degree of milling and polishing (OECD Environment, 2004). On recognition of world-wide protein malnutrition greater emphasis has been given for improving rice protein content, either through breeding for high-protein cultivars or through manipulation of environment. Protein content of milled rice grains ranged from 4.91% to 12.08% with the mean of 6.63%. Donor lines for breeding rice varieties with optimum protein quality were identified as potential donor parents for genetic improvement of rice for nutritious grains (Banerjee *et al*., 2011). Similar type of research work has been done by this present study. The range of protein content of parents for this study varied from 8.5% to 10.7%. The range of protein content of this present study was within the range of protein content of those data reported by Juliano and Villareal, (1993) and Choudhury *et al*., (1999). Examination of over two thousand rice varieties found protein content ranged for 4% to 14% in Asian rice varieties (*Oryza sativa*) and 9% to 14% in African varieties (*Oryzaglaberima*) (Juliano and Villareal, 1993). The range of protein content of rice varieties varied from 6.9% to 11.4% reported by (Choudhury *et al*., 1999).

Intermediate or average percent of protein evolved in F_1 generation was reported by Totok*et al*., (2012) in accordance with the present findings. In this study protein content of Motichak × BRRI dhan28 (F_1 generation), BRRI dhan28 and Motichak had 9.1%, 8.6% and 10.5% respectively. So, the hybrid showed a protein content of 9.1%, which was 5.8% higher and 13.3% lower than those of the parent BRRI dhan28 and Motichak respectively. Though the findings of this study were partially similar but in some aspect it was dissimilar to that data reported by Ahmed *et al*., (2008), who reported that a significant increase in seed protein content was observed in an interspecific hybrid between *Oryza sativa* ssp. indica and the wild species *Oryzanivara*. The hybrid showed a protein content of 12.4%, which was 28% and 18.2% higher than those of the parent *O. nivara* and IR 64, respectively. The increase in protein content was dependent on the genetic background of the rice variety used in the hybridization.

Rice genotypes are potential for consumer's preferences due to its amylose content. So, amylose content of rice kernel can be improved either through breeding for high-amylose cultivars or through manipulation of environment. The range of amylose content of parents for this study varied from 22% to 28%. The range of amylose content of this present study was almost similar to that data reported by Biswas *et al*., 2000; amylose content of aromatic rice varied from 21.6% to 27.4%.

Amylose content of Motichak × BRRI dhan28 (F_1 generation), Motichak and BRRI dhan28 were 26.7%, 26% and 28% respectively; amylose content of Molladigha × BRRI dhan28 (F_1 generation), Molladigha and BRRI dhan28 were 27.2%, 27% and 28% respectively as well as amylose content of Magoibalam × BRRI dhan55 (F_1 generation), Magoibalam and BRRI dhan55 were 23.6%, 27% and 22% respectively. It was found that the high amylose content of F_1 generationwas similar to that parentwith high amylose content.On the other hand, intermediate amylose content of F_1 generationwas resultedinto theparentwith high and intermediate amylose contentin this study.Thefindings of this study were dissimilar to those data reported by Kumar and Khusu (1986) as well as Rafii*et al*., (2014). A significant increase in amylose content was found among the F_1generation. Amylose content of 25.61% was observed in F_1 seeds of crosses between the 21.74% amylose content of IR24632-34 and 27.26% amylose content of IR8 parents (Kumar and Khusu, 1986). Amylose content varied among the progenies. Combinations of intermediate and high amylose content resulted into the F_1 progenies with high amylose content (Rafii*et al*., 2014).

Chapter 6

CONCLUSION

A good number of cultivars stands out as good sources of more than one quality characters. The study provided information on the agronomic characters of long, medium and short grain cultivars. Among the long grain rough rice cultivars such as Boradudhkalam, Dudhkalam, Gohatibinni, Harilaxmi, Kanaibansi, Patnai-231 and Shata(having 4.0-5.2 t/ha yield) as well asof the medium grain rough rice cultivarssuch asGanjia, Gojalgoria, Jhoshuoa, Kajalsail, Kanaklota, Maloti and Tilokkajal(having 4.0-4.5 t/ha yield) were found promising.

The study also included information on the morphological and physical characters of long, medium and short grain cultivars. Out of 129 cultivars, only 24 had aroma, 46 had red pericarp, 16 had long slender and 85 had translucent grain. The cultivars having long slender grain with translucent kernel are preferred all over. Cultivars of Karailadhan, Pakhisail and Neda were long slender with translucent grainhavinggreater than 7.2 mm milled rice length.

The milling rough rice cultivars showed that most of the dehulled kernel had brown pericarp but others red pericarp. Long rough rice cultivars such asBoradudhkalam,Dudhkalam, Gohatibinni, Harilaxmi, Patnai-231 andShataas well as medium rough rice cultivarssuch asGanjia, Gojalgoria, Jhoshuoa, Kajalsail, Kanaklota, Maloti and Tilokkajal had acceptable (> 67%) millingoutturn.

Results show that cultivars varied in amylose content from 5.0-29% and elongation ratio from 1.5-2.2. None of the long slender grain had more than 2.0 elongation ratio. Medium grain cultivars such asGanjia,Kanaklota, Maloti and Tilokkajal had more than 1.9 elongation ratio.

Analysis of mineral contents (phosphorous, calcium, magnesium, nitrogen, potassium, sodium, iron and zinc) of the total cultivars showed that phosphorous, sodium and iron content was higher in the tested local cultivars than the HYVs irrespective of grain size and shape. Zinc content was significant and positively correlated with iron content.

Proximate composition, fractionation of protein and amino acid composition of some promising cultivars were analyzed. The invitro protein digestibility of Magoibalam, Motichak, Neda, Molladigha and Boylam were found satisfactory (67-78%). These 5 cultivars had higher protein content (>10%). Among them, Magoibalam showed the highest protein digestibility.

In vitro starch digestibility of high amylose, intermediate amylose and low amylose cultivars showed that digestibility varied among amylose groups. Low amylose cultivars of Athabinni, Kalabinni-1, Kanaibansi and Ledabinni showed high starch digestibility as well as high amylose cultivars of Boylam, Magoibalam and Motichak showed lowest starch digestability.

Genetic diversity of *Waxy* gene in selected rice cultivars was evaluated by using microsatellite marker and cleaved amplified polymorphic sequence marker. Results indicate that Microsatellite marker (RM190) and cleaved amplified polymorphic sequence marker (RM190F-GBSSW2R/*AccI*) had efficacy to differentiate amylose status on the basis of allelic variation and single nucleotide (G/T) polymorphism of the *Waxy* gene. The hybrid vigor of Motichak × BRRI dhan28 (F_1 seed) has shown plant height of 103 cm (which is greater than BRRI dhan28 but less thanMotichak), protein content of 9.1% (which is greater than BRRI dhan28 but less thanMotichak) as well as amylose content of 26.7% (which is greater than Motichakbut less than BRRI dhan28). Three crosses were made as successful F_1 hybridization. Evaluation of F_1 hybridization and its confirmation on the basis of morphological and nutritional performance was found promising.

It is concluded that cultivars of long slender, medium slender and translucent grain with higher head rice yield, higher elongation and volume expansion as well as higher protein and amylose content may play vital role in improving grain qualities having excellent physicochemical and nutritional values. More over information derived from present study may be helpful in breeding purpose.

Chapter 7

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