INFLUENCE OF NITROGEN AND PHOSPHORUS ON GROWTH AND YIELD OF HYBRID RICE

MD. HASANUZZAMAN

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY,

DHAKA-1207

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INFLUENCE OF NITROGEN AND PHOSPHORUS ON GROWTH AND YIELD OF HYBRID RICE

BY

MD. HASANUZZAMAN

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Approved by:

……………………………..	…………………………..
(Dr. Md. Hazrat Ali)	**(Dr. Md. Fazlul Karim)**
Professor	**Professor**
Supervisor	**Co-supervisor**

…………………………………

(Dr. Md. Fazlul Karim)
Chairman
Examination Committee

CERTIFICATE

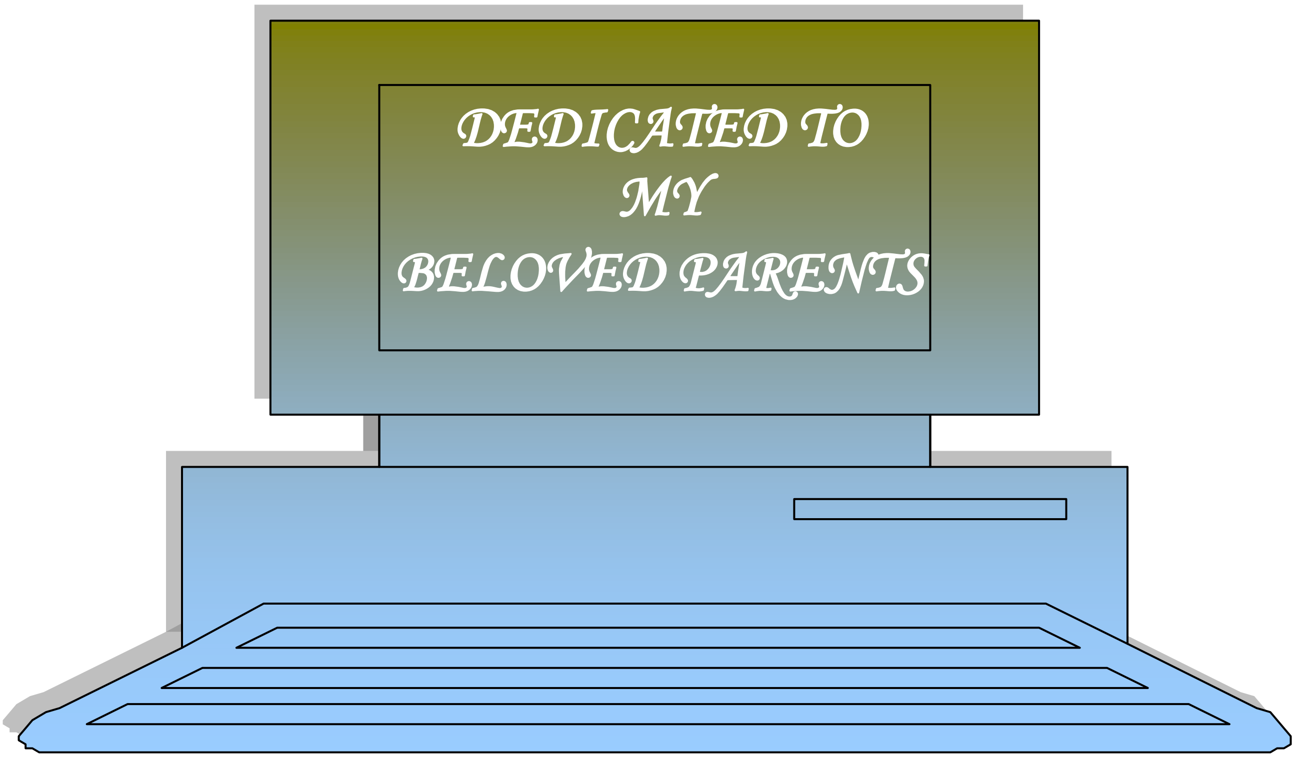
This is to certify that the thesis entitled, "**INFLUENCE OF NITROGEN AND PHOSPHORUS ON GROWTH AND YIELD OF HYBRID RICE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the result of a piece of *bonafide* research work carried out by **MD. HASANUZZAMAN,** Registration No. **05-01644** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:

Place: Dhaka, Bangladesh

(Dr. Md. Hazrat Ali)
Professor
Supervisor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The author

ABSTRACT

The Experiment was carried out at Sher-e-Bangla Agricultural University, Dhaka during the period of November, 2010 to May 2011 to study the influence of levels of nitrogen and phosphorus on the growth and yield of hybrid Heera1. The experiment was laid out on split plot design with three replications having nitrogen fertilizer in the main plot and phosphorus fertilizer in the sub plot. There were six nitrogen fertilizer levels *viz.*, N_0=no nitrogen, N_1=80 kg N ha^{-1}, N_2=urea supergranules (2.7 g) @ 75 kg N ha^{-1}), N_3=120 kg N ha^{-1}, N_4=160 kg N ha^{-1}, N_5=200 kg N ha^{-1} and four phosphorus fertilizer levels *viz.*, P_0=no phosphorus, P_1=30 kg P_2O_5 ha^{-1}, P_2=50 kg P_2O_5 ha^{-1}and P_3=70 kg P_2O_5 ha^{-1}. Urea was top dressed in three equal splits at 10, 35 and 55 DAT. The USG (2.7 g) was placed at 5-10 cm soil depth at 10 DAT in the centre of four hills in alternate rows @ 1 granule in one spot to supply 75 kg N ha^{-1}. Results indicated that the effect of nitrogen showed significant variation in respect of all growth, yield contributing characters and yield. At harvest, highest plant height (96.74 cm), tillers hill^{-1} (14.22), LAI (7.72), total dry matter (66.26 g), effective tillers hill^{-1} (13.63), panicle length (24.29 cm), filled grains panicle^{-1} (154.67), total grains panicle^{-1} (159.20), 1000 grain weight (29.35 g), grain yield (9.42 t ha^{-1}), straw yield (13.33 t ha^{-1}), biological yield (22.75 t ha^{-1}) was obtained from the application of USG. About 10% more grain yield was measured from USG than PU. Phosphorus @ 50 kg P_2O_5 gave the highest grain yield (7.85 t ha^{-1}). Interaction effect showed that application of USG along with 50 kg P_2O_5 ha^{-1} gave the highest (9.83 t ha^{-1}) grain yield. On the other hand application of 160 kg N ha^{-1} and 120 kg N ha^{-1} along with 50 kg P_2O_5 ha^{-1} gave similar grain yield as 8.83 t ha^{-1} and 7.67 t ha^{-1}, respectively.

CONTENTS

CONTENTS (Cont'd)

CONTENTS (Cont'd)

CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ACRONYMS

AEZ	=	Agro- Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centimeter
cv.	=	Cultivar
CGR	=	Crop growth rate
CAR	=	Conventional application rate
DAT	=	Days after transplanting
^{0} C	=	Degree Centigrade
DF	=	Degree of freedom
DAP	=	Diammonium phosphate
DMA	=	Dry matter accumulation
DMRT	=	Duncan' Multiple Range Test
EC	=	Emulsifiable Concentrate
et al.	=	and others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
FYD	=	Farmyard manure
g	=	Gram
GDP	=	Gross domestic product
HI	=	Harvest Index
HYV	=	High yielding variety
hr	=	hour
IRRI	=	International Rice Research Institute
Kg	=	kilogram
LV	=	Local variety
LAI	=	Leaf area index
m	=	Meter
m^2	=	meter squares

MPCU	=	Mussorie phos-coated urea
MV	=	Modern variety
MOP	=	Murate of potash
mm	=	Millimeter
viz.	=	namely
N	=	Nitrogen
NFAA	=	Nitrogen fertilizer application amount
ns	=	Non significant
%	=	Percent
CV %	=	Percentage of Coefficient of Variance
P	=	Phosphorus
K	=	Potassium
ppm	=	Parts per million
PU	=	Prilled urea
SAU	=	Sher-e- Bangla Agricultural University
S	=	Sulphur
SRDI	=	Soil Resource and Development Institute
SCU	=	Sulphur coated urea
SHR	=	Super hybrid rice
t ha^{-1}	=	Tons per hectare
USG	=	Urea supergranules
UDP	=	Urea deap placement
Zn	=	Zinc
TSP	=	Triple super phosphate
TDM	=	Total dry matter
Kg ha^{-1}	=	Kilogram per hectare

Chapter 1

Introduction

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop of the world and the staple food of more than 3 billion people or more than half of the world's population. Rice is grown in more than a hundred countries with a total harvested area of nearly 160 million hectares, producing more than 700 million tons every year (IRRI, 2010). Rice grain is rich in nutrients and contains a number of vitamins and minerals. Rice provides 21% of global human per capita energy and 15% of per capita protein (IRRI, 2010).

Total rice production in Bangladesh was about 10.97 million tons in 1971 when the country's population was only about 70.88 million whereas the country is now producing about 33.54 million tons rice to feed her 142.3 million people as staple food (BBS, 2010). Rice is grown in Bangladesh under diverse ecosystem, irrigated, rainfed and deep water condition in three distinct seasons namely *aus, aman* and *boro.* The area and production of total rice in Bangladesh are about 11.35 million hectare and 31.98 million metric tons, respectively where *boro* covers the largest part of about 4.70 million hectare with the production 18.06 million metric tons. The area and production of hybrid rice in *boro* season were about 6.86 lac hectares and 32.2 lac metric tons, respectively (BBS, 2010). The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. But the average yield of rice is poor (4.34 t ha^{-1}) in Bangladesh

(BRRI, 2011). On the other hand, rice production area is decreasing day by day due to high population pressure. The possibility of horizontal expansion of rice production area has come to stand still (Hamid, 1991). Therefore, attempts should be taken to increase the yield per unit area through use of comparatively high yielding varieties along with judicial fertilizer management.

Introduction of hybrid rice is an important step towards augmentation of rice yields. Hybrid rice yield potential of the rice plant by 15-20% or more with the application of almost same amount of agricultural inputs (Husain *et al*., 2000). Hybrid rice out yielded the existing conventional High Yielding Varieties (HYVs) by 15-20% in India, Bangladesh and Vietnam (Janaiah *et. al*., 2002). The Bangladesh Rice research Institute (BRRI) started hybrid rice research and developed four BRRI hybrid dhan. Some commercial companies of Bangladesh and BADC are marketing hybrid seed imported from different countries like China, Japan, India and Philippine. The major hybrid rice varieties which are cultivated in Bangladesh are BRRI hybrid dhan1, BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, Jagoron, Sonarbangla, Aftab LP 50, SL-8H and Heera etc.

Proper fertilization is an important management practice which can increase the yield of hybrid rice. Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Youshida, 1981). Nitrogen is the top most important nutrient and it is a key input for rice production in the rice growing countries as well in Bangladesh (Hasan, 2002). Nitrogen is required in adequate amount at early, at midtillering, and panicle initiation stage for better grain development (Ahmed *et al*. 2005). According to Crasswell and De datta (1980) broadcast application of urea on the surface soil causes losses up to 50% but point placement of urea supergranules (USG) in 10 cm depth results negligible loss. USG is a fertilizer that can be applied in the root zone at 8-10 cm depth of soil (reduced zone of rice soil) which can save 30% nitrogen than prilled urea, increase absorption rate, improve soil health and ultimately increase the rice yield (Savant *et al*., 1991)

Among potential of three primary elements (NPK), phosphorus is relatively absorbed by the plants in small amount than other two, but plays an equally important role. Phosphorus deficiency results in decreased leaf number, leaf blade, reduced panicles plant^{-1}, grain panicle^{-1}, and reduced filled grain panicle^{-1} (Aide and picker,1996). Phosphorus status in Bangladesh soil is quite low. So application of phosphatic fertilizer is essential to obtain higher yield. However, the major plant nutrient element nitrogen and phosphorus, plays a vital role in rice production.

Many farmers are using very low and others are using very high level of nitrogen and phosphorus in hybrid rice production. Both lower and higher level, no doubt affects the crop growth and development. Lower level of nitrogen drastically reduce yield and excessive nitrogen encourage excessive vegetative growth that makes the plants weak and causes lodging and plants become susceptible to insect, pest and diseases leading to reduced yield and polluted the environment. Besides, phosphorus is in fixation with soil complex within a very short period of application rendering more than two-third unavailable (Sahrawat *et al*. 2001). So it is necessary to know the optimum levels of nitrogen and phosphorus for maximum growth, development and expected yield of hybrid rice.

Keeping all the points in mind mentioned above, the present piece of research work was under taken with the following objectives.

- Identify the optimum level of nitrogen on hybrid rice.
- Identify the optimum level of phosphorus on hybrid rice.
- Study the effect of urea super granules on hybrid rice.
- Study on interaction effect of nitrogen and phosphorus on the growth and yield of hybrid rice.

Chapter 2
Review of literature

REVIEW OF LITERATURE

The continuous and unbalanced use of the chemical fertilizers under intensive cropping systems has been considered to be the main cause for declining crop yield and environmental degradation. All essential elements must be present in optimum amounts and in forms usable by plants. Urea and TSP are chemical fertilizers most commonly applied by rice farmers. Urea (nitrogen) is a major component of proteins, hormones, chlorophyll, vitamins and enzymes, essential for rice. Rice plants require a large amount of nitrogen at the early and mid-tillering stage to maximize the number of panicles (Datta, 1988). The recommended doses of other nutrients are also necessary for potential rice yield. Considering the above point, available literatures were reviewed under nitrogen and phosphorus application for hybrid and inbreed rice.

2.1 Effect of nitrogen

Nitrogen absorbed by rice during the vegetative growth stages contributed in growth during reproduction and grain-filling through translocation (Bufogle *et al*. 1997; Norman *et al*., 1992). Nitrogen is very essential for the growth and development of crops. It enhances biomass and seed yield subject to the efficient water supply. Lack of N results stunted growth, pale yellow color, small grain size and poor vegetative as well as reproductive performance. Nitrogen is an essential component of amino acid and related protein of the plant structure. An increase in yield of cereals with increasing rate of nitrogen has been reported earlier (Khan *et al*., 1994).

2.1.1 Effect on growth character

2.1.1.1 Plant height

Salem (2006) reported that the nitrogen levels had a positive and significant effect on growth parameters of rice plants. Increasing nitrogen levels up to 70 kg ha^{-1} significantly increased plant height. The highest plant height was recorded about 92.81 cm with 70 kg N ha^{-1}.

Ahmed *et al*. (2005) reported that among 5 levels, 80 kg N ha^{-1} gave the highest plant height (155.86 cm) and the height decreased gradually with decreased levels of nitrogen fertilizer application.

Meena *et al*. (2003) reported that application of 200 kg N ha^{-1} significantly increased the plant height (127.9 cm) of rice while they applied another dose, 100 kg N ha^{-1}.

Pot experiments were conducted by Wang *et al*. (2002) to determine the effect of nitrogen levels no nitrogen, low nitrogen, medium nitrogen, high nitrogen and super high nitrogen on the growth of plants and leaves in hybrid rice Shanyou 64 and conventional rice Kinmaze. They found that the plant height increased with increasing nitrogen levels.

Kumar and Subbaiah (2001) conducted an experiment in Andhra Pradesh, India to identyfy the response of the rice hybrid PAC-803 and cv. Ajaya to various N sources, i.e. urea, calcium ammonium nitrate, ammonium sulfate and diammonium phosphate (DAP) + urea. They reported that tallest Ajaya (101.03

cm) and PAC-803 (85.18 cm) plants were obtained with calcium ammonium nitrate and ammonium sulfate, respectively.

A field experiment was conducted by Geethadevi *et al.* (2000) in India to determine the effect of different nitrogen rates (0, 50, 100 and 150 kg ha^{-1}) and spacing (15 x 10 or 20 x 10 cm) on the growth and yield of hybrid rice. Among N rates, treatment with 150 kg N ha^{-1} recorded the highest values for plant height (87.20 cm).

Mishra *et al.* (2000) conducted a field experiment in Bhubaneswar, Orissa, India, and reported that rice cv. Lalate was given 76 kg N ha^{-1} as USG at 0, 7, 14 for 21 days after transplanting (DAT), and reported that USG application increased plant height.

Experiments were conducted by Rajendran and Veeraputhiran (1999) to study the effects of 4 nitrogen levels (0, 75, 150 and 225 kg ha^{-1}) and 3 sowing rates in the nursery (10, 20 and 30 g m^{-2}) on hybrid rice ADTRH1. Nitrogen was applied at 3 equal splits namely: 7 days after transplanting, active tillering and panicle initiation stages. Observation upon harvest revealed that plant height was found with 225 kg N ha^{-1}.

Vijaya and Subbaiah (1997) showed that plant height of rice increased with the application of USG and were greater with the deep placement method of application both N and P compared with broadcasting.

2.1.1.2 Tillering pattern

BRRI (2008a) conducted an experiment to study the comparetive study of some promising lines with BRRI modern rice varieties to different nitrogen levels *viz*. 0, 30, 60, 90, 120 and 150 kg N ha^{-1}. It was reported that tiller production with N @ 120 kg ha^{-1} produced significantly higher tiller than those of lower N levels.

BRRI (2006) reported that the maximum tillers $hill^{-1}$ (10.2) was produced with 120 kg N ha^{-1} compared to 90 and 0 kg N ha^{-1} application.

A field experiment was conducted by Lang *et al*. (2003) to study the effect of different fertilizer application rates on seedling of Jinyou 207, Guihuanian and Teyou 524 were sown in no-tillage plots situated in 3 different counties in Guangxi, China. At an early stage of growth, the seedlings were subjected to one of three nitrogen fertilizer treatments. Treatment A used a conventional application rate (CAR) of 157-5-172.5 kg ha^{-1}N, treatments B and C used CAR + 10% and CAR + 20%, respectively. They found that the increase in nitrogen fertilizer application rate increased the speed of seedling establishment and tillering peak.

Wang *et al*. (2002) reported that the tiller number increased with increasing nitrogen levels.

Kumar and Subbaiah (2001) noted that application of DAP + urea resulted in the highest number of tillers m^{-2}.

Rajendran and Veeraputhiran (1999) observed that productive tillers m^{-2} increased as the N rate increased.

2.1.1.3 Leaf area index

Masum *et al*. (2008) conducted an experiment to study the effect of four levels of seedling $hill^{-1}$ *viz*; 1, 2, 3 and 4 and two forms of nitrogen – prilled urea (PU) and urea supergranules (USG) on yield and yield components of modern

(BRRI dhan44) and traditional (Nizershail) transplant *aman* rice. They reported that leaf area index significantly higher in USG receiving plant than prilled urea.

Hamidullah *et al*. (2006) conducted an experiment on growth and yield performance of BINA dhan 5 in *boro* season as affected by nitrogen levels *viz.* 80, 120 and 160 kg N ha^{-1}. They reported that leaf area index was peak at 60 DAT and decline thereafter, highest 5.53 obtained with 160 kg N ha^{-1} at 60 DAT.

Miah *et al.* (2004) found that LAI was significantly higher in USG receiving plots than urea at heading.

A field test with the super hybrid rice (SHR) combination Liangyoupeijiu was conducted by Tang *et al*. (2003) in Changsha, Hunan, China. Nine treatments were used, including 0, 60, 120, 180, 240, 180, 130, 225 and 160 kg N ha^{-1}. They reported that higher N fertilizer application amount ensured a higher leaf area index.

2.1.1.4. Total dry matter production

Xie *et al*. (2007) reported that increased split application of N from control to 140 kg N ha^{-1} increased dry matter accumulation (DMA) of different growth stages of Jinzao22 and Shanyou63 rice varieties and after that dose the DMA reduced due to the losses of N by volatilization.

Sing and Modgal (2005) noted that dry matter accumulation (DMA) and concentration and uptake of nitrogen increased with increasing level of N at all the stages of crop growth.

Miah *et al.* (2004) noted that USG applied plots gave higher TDM compared to urea irrespective of number of seedling transplanted hill^{-1}.

Fu *et al*. (2000) conducted a field experiment in Zhejiang Province, China to evaluate the nitrogen fertilizers (0, 100, 150, 180, 225, 270, and 300 kg N ha^{-1} as urea, two-thirds top-dressed as basal and one third top dressed 7 days after transplanting, on dry matter and N partitioning in hybrid rice 518. They reported that higher N applications significantly increased dry matter partitioning of leaf at the vegetative stage. Partitioning of dry matter to leaves decreased as the N concentration in the leaves decreased. Leaf partitioning of absorbed N, compared to dry matter, was higher and varied little during early vegetative growth, but varied greatly from panicle initiation onwards, probably due to competition for N among leaves, stem and the developing panicle.

A field experiment was conducted by Geethadevi *et al. (*2000) in Karnataka, India to determine the effect of different nitrogen rates (0, 50, 100 and 150 kg N ha^{-1}) and spacing (15 cm x 10 cm or 20 cm x 10 cm) on the growth and yield of hybrid rice. Among N rates, treatment with 150 kg N ha^{-1} recorded the highest values for total dry matter per plant (57.08 g).

Das (1989) reported that the dry matter yield of rice were higher with application of USG of various forms and methods of application of N fertilizers to rice grown under flooded conditions, placement of N as USG (1 and 2 g size) in the root zone at transplanting was the most effective in increasing dry matter production and were the lowest with urea applied as a basal drilling.

2.1.1.5 Crop growth rate:

A field experiment was conducted by Das and Panda (2004) in Bhubaneswar, Orissa, India, to study the effects of N (0, 60, 120 or 180 kg ha^{-1}) and K (0, 40, 80 or 120 kg ha^{-1}) on the growth rate of hybrid rice 6102. N (urea) was applied as a basal dressing (25%), and as a top dressing at 18 days after transplanting (DAT; 50%) and at the panicle initiation stage (25%). K (K_2O) was applied during transplanting. Irrespective of treatment difference, Crop growth rate (CGR) was greater at 40-60 DAT and lower at 20-40 DAT. The increase in the N rate increased CGR. The highest CGR (22.52 g day^{-1} m^{-2}) was obtained with 80 kg K_2O ha^{-1}.

2.1.2 Effect on yield contributing character

2.1.2.1 Effective tillers $hill^{-1}$

Awan *et al*. (2011) conducted an experiment to study the effect of different nitrogen levels (110, 133 and 156 kg N ha^{-1}) in combination with different row spacing (15 cm, 22.5 cm and 30 cm). They noted that maximum level of N (156 kg N ha^{-1}) produced maximum effective tillers irrespective of spacing.

A field experiment was conducted by Singh and Shivay (2003) at the Research Farm of the Indian Agricultural Research Institute, New Delhi, India to study the effect of coating prilled urea with eco-friendly neem formulations in improving the efficiency of nitrogen use in hybrid rice. Two rice cultivars, hybrid rice (NDHR-3) and Pusa Basmati-1, formed the main plots, with the levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and various forms of urea at 120 kg N ha^{-1}in the subplots. They found that increasing levels of nitrogen significantly increased the number of effective tillers $hill^{-1}$.

Meena *et al*. (2002) studied the response of hybrid rice to nitrogen (0, 100 and 200 kg ha^{-1}) and potassium application (0, 75 and 150 kg ha^{-1}) at the research farm of the IARI, New Delhi. They observed that application of nitrogen significantly increased the effective tillers.

Jee and Mahapatra (1989) observed that number of effective tillers m^{-2} were significantly higher with 90 kg N ha^{-1}as deep placed USG than split application of urea.

Rama *et al.* (1989) mentioned that effective tiller increased significantly when nitrogen level increased from 40 to 120 kg N ha^{-1} as different modified urea materials and USG produced significantly higher effective tiller than split application of PU.

2.1.2.2 Panicle length

Hasanuzzaman *et al*. (2009) conducted an experiment to study the economic and effective method of urea application in rice crop. They noted that urea supergranules produced longest panicle (22.3 cm).

Islam *et al*. (2008) conducted an experiment to study the effect of nitrogen and number of seedlings per hill on the yield and yield components of T. *aman* rice (BRRI dhan 33). They noted that panicle length, number of grain panicle^{-1} increased with the application rate of N up to 100 kg ha^{-1} and then declined.

Singh and Shivay (2003) found that increasing levels of nitrogen significantly increased the panicle length.

Meena *et al*. (2002) observed that increase in nitrogen fertilizer application rate enhanced length and weight of panicles of hybrid rice.

Patel and Mishra (1994) carried out an experiment with rice cv. IR36 and were given 0, 30, 60 or 90 kg N ha^{-1} as Muossorie rock phosphate-coated urea, *neem* cake-coated urea and gypsum coated urea, USG or PU. The coated materials as incorporated before transplanting and USG as placed 5-10 cm deep a week after transplanting and urea as applied in 3 split doses. They showed that N management practices had no significant effect on panicle length and percent sterility.

Sen and Pandey (1990) carried out a field trial to study the effects of placement of USG (5, 10 or 15 cm deep) or broadcast PU @ 38.32 kg N ha^{-1} on rice. They revealed that all depths of USG placement resulted in higher yield characters than broadcast PU; however, differences except for panicle lengths were not significant.

2.1.2.3 Filled grains $panicle^{-1}$ and unfilled grains $panicle^{-1}$

Masum *et al*. (2010) reported that placement of N fertilizer in the form of USG @ 58 kg N ha^{-1} produced the highest number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ which ultimately gave the higher grain yield than split application of urea.

A field experiment was conducted by Edwin and Krishnarajan (2005) to study the effects of irrigation and N fertilizer treatments on the yield of rice hybrid variety CoRH2 in Coimbatore, Tamil Nadu, India. They suggested that N supplied at 7 DAT, 21 DAT, panicle initiation stage and first flowering stage gave the highest filled grains.

Lang *et al*. (2003) found that the increase in nitrogen fertilizer application rate enhanced grains per panicle, effective panicles per plant, and total florets per plant.

Meena *et al*. (2002) noted that increase in nitrogen fertilizer application rate enhanced number of grains and filled grains of hybrid rice.

2.1.2.4 1000 grain weight

Maitti *et al*. (2003) conducted an experiment to study the effects of nitrogen fertilizer rate (0, 120, and 140 kg ha^{-1}) on the performance of 1 cultivar (IET-4786) and 4 hybrid varieties (ProAgro 6Y213, ProAgro 6Y3024, ProAgro 6111N, and ProAgro 6201) of rice in Mohanpur, West Bengal, India. The nitrogen fertilizer was applied during transplanting (50%) and at the tillering and panicle initiation stages (50%). They reported that the application of 140 kg N ha^{-1} resulted in the highest increase in grain yield (by 76.2%), number of panicles (by 109.00%), number of filled grains per panicle (by 26.2%), and 1000-grain weight (5.80%) over the control, and the highest nitrogen (136.701 kg ha^{-1}), phosphorus (132.029 kg ha^{-1}), and potassium (135.167 kg ha^{-1}) uptake.

Meena *et al*. (2002) reported that increase in nitrogen fertilizer application rate increased 1000-grain weight of hybrid rice.

Hasan *et al.* (2002) determined the response of hybrid (Sonar Bangla-1 and Alok 6201) and inbred (BRRI Dhan 34) rice varieties to the application methods of urea supergranules (USG) and prilled urea (PU) and reported that the effect of application method of USG and PU was not significant in respect of panicle length, number of unfilled grains $panicle^{-1}$ and 1000-grains weight.

Ahmed *et al.* (2000) conducted a field experiment to study the effect of point placement of urea supergranules (USG) and broadcasting prilled urea (PU) as sources of N in T. *aman* rice. USG and PU were applied @ 40, 80, 120 or 160

Kg N ha^{-1}. They suggested that USG was more efficient than PU in producing panicle length, filled grains panicle^{-1} and 1000-grain weight.

Roy *et al.* (1991) compared deep placement of urea supergranules (USG) by hand and machine and prilled urea (PU) by 2 to 3 split applications in rainfed rice. They obtained highest 1000-grain weight from USG treated plots.

Thakur (1991) observed that yield attributes differed significantly due to levels and sources of' nitrogen at 60 kg N ha^{-1} through USG produced the highest panicle weight, number of grains panicle^{-1}, 1000- grain weight.

2.1.2.5 Effect on grain yield and straw yield

BRRI (2009) conducted an experiment on study of N release pattern from USG and prilled urea under field condition and its effect on grain yield and N nutrition of rice with three doses of N namely 50, 100 and 150 kg N ha^{-1}from two types of urea e.g. prilled (PU) and urea super granules (USG) were tested as treatment. Result showed that the highest grain yield was recorded when N applied @ 100 kg N ha^{-1} both from USG and PU and the highest straw yield was obtained in PU @ 150 kg N ha^{-1}.

BRRI (2008b) conducted an experiment on the title of response of MVs and hybrid entries to added N in a rice rice cropping pattern. Six N doses 0, 40, 80, 120, 160 and 120 kg N ha^{-1} were tested and resulted that grain yield of hybrid responded up to 120 kg N ha^{-1}.

Kabir *et al*. (2009) conducted an experiment to find out the effect of urea super granules (USG), prilled urea (PU) and poultry manure (PM) on the yield and yield contributes of transplant *aman* rice. They observed that the highest grain yield (5.17 t ha^{-1}), straw yield (6.13 t ha^{-1}) and harvest index (46.78%) were found from full dose of USG.

Lin *et al*. (2008) conducted an experiment to find out the effect of plant density and nitrogen fertilizer rates (120, 150, 180 and 210156 kg N ha^{-1}) on grain yield and nitrogen uptake of hybrid rice. They observed that there was a better response to N fertilization, as increasing N application from 120 to 180 kg N ha^{-1} (by 50%) raised yield by 17%. Raising the application rate to 210 kg N ha^{-1} (by 75%) boosted yield by 24.1%.

Field experiments were conducted by Wan *et al*. (2007) in China to study the effects of different nitrogen (N) fertilizer application regimes (basal and panicle applications) on the yield, quality and N use efficiency of super japonica hybrid rice cv. Changyou 1. They indicated that yield was significantly influenced by the different N fertilizer application regimes. The regime with the highest yield was at the basal to panicle application ratio of 58.34:41.66 and equal split panicle applications at the fourth and second leaf age from the top.

A study was conducted by Mubarak and Bhattacharya (2006) under the Gangetic alluvial soil of West Bengal, India, to investigate the response of hybrid rice cultivars to various levels of nitrogen and potassium. Significantly higher values for growth and grain yield were obtained with the application of 150:60:80 kg NPK ha^{-1}, which was at par with 150:60:40 kg NPK ha^{-1}.

A study was conducted by Ingale *et al*. (2005) to determine the effects of seedling ages at transplanting (25, 40 and 55 days), number of seedlings per hill (one or two) and nitrogen rates (50, 100 and 150 kg ha^{-1}) on the yields of Sahyadri rice hybrid. They found that the application of 150 and 100 kg N ha^{-1} resulted in significantly higher yields than treatment with 50 kg N ha^{-1}.

Edwin and Krishnarajan (2005) reported that N supplied at 7 DAT, 21 DAT, panicle initiation stage and first flowering stage gave the highest grain yield and straw yield and lowest level of spikelet sterility (25.30%).

Saiti *et al*. (2005) conducted an experiment to evaluate three traditional and three improved cultivars which were grown under four fertilizer treatments: no added fertilizer, nitrogen only (N; 90 kg N ha^{-1}), phosphate only (P; 50 kg P ha^{-1}), and N and P (NP) at three locations. The two improved cultivars, IR55423-01 and B6144-MR-6-0-0 out-yielded traditional cultivars in all locations and fertilizer treatments. N fertilizer application increased grain yields of the two improved cultivars from 3.1 to 4.0 t ha^{-1} while increasing those of traditional cultivars from 1.6 to 1.9 t ha^{-1}.

A field experiment was conducted by Rakesh *et al*. (2005) at Research farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India, to determine the response of hybrid rice cv. MPH-501 to different nitrogen (40, 80, 120 and 160 kg N ha^{-1}) and potassium levels (30, 60, and 90 kg K_2O ha^{-1}). The application of 160 kg N and 60 kg K_2O ha^{-1} significantly influenced the growth and yield attributes of hybrid rice and produced higher grain and straw yield.

Nitrogen fertilizer when applied as USG was reported to have increased grain yield by around 18% and saved around 32% N in wetland rice over prilled urea and appeared to be a good alternative N fertilizer management for rice production (Annon., 2004).

A field experiment was conducted by Upendra *et al*. (2004) at Pusa, Bihar, India to evaluate two newly developed rice hybrids (KHR2 and DRRH1) and one local control (Boro 5) growth under 10 different nitrogen-potassium (NK) fertilizer levels. Data were recorded for plant height, effective tillers m^{-2}, panicle length, test weight, grain yield, straw yield, harvest index and benefit:cost ratio. Both rice hybrids performed better than the local cultivar. Yield and related characters increased with increasing fertilizer levels up to 150 kg N ha^{-1} and 80 kg K ha^{-1}.

A study was conducted by Verma *et al*. (2004) in Madhya Pradesh, India to investigate the effect of planting date (20 July; and 5 and 20 August) and N rates (50, 100 and 150 kg ha^{-1}). They reveled that N at 100 and 150 kg ha^{-1} resulted in the highest yield.

Singh and Shivay (2003) found that increasing levels of nitrogen significantly increased the grain and straw yields.

Maitti *et al*. (2003) reported that the application of 140 kg N ha^{-1} resulted in the highest increase in grain yield.

A field experiment was conducted by Balasubramanian (2002) in Madurai, Tamil Nadu, India to study the effect of levels (0, 150, 200 and STCR-based N) and time of application (3 or 4 splits) of nitrogen on 'CoRH 1' hybrid rice. Hybrid rice recorded good response to N up to 256.7 kg ha^{-1} (STCR-based N). Higher levels of N improved the growth and yield of rice. The STCR-based N applied in 4 splits (basal, active tillering, panicle initiation and panicle emergence) registered the maximum grain yield, followed by 200 kg N ha^{-1} applied in 4 splits.

Meena *et al*. (2002) resulted that application of nitrogen significantly increased grain and straw yields of hybrid rice up to the level of 200 kg N ha^{-1}.

A field experiment was conducted by Devasenamma *et al*. (2001) in Andhra Pradesh, India to study the performance of rice hybrids (APHR-2, DRRH-1, MGR-1, TNRH-16 and NLR-33358) at various N fertilizer rates (0, 60, 120 and 180 kg ha^{-1}). The highest values for yield and yield components were obtained with 180 kg N ha^{-1}.

Ahmed *et al.* (2000) revealed that USG was more efficient than PU at all respective levels of nitrogen in producing grain and straw yields. Placement of USG @ 160 Kg N ha^{-1} produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg N ha^{-1} as USG and significantly superior to that obtained from any other level and source of N.

Rajendran and Veeraputhiran (1999) suggested that grain yield increased as the N rate increased. The highest straw yield (13.1 t ha^{-1}) was found with 225 kg N ha^{-1}.

Balaswamy (1999) found that in an experiment deep placement of nitrogen as urea supergranules reduced the dry weight of weeds resulting in more panicles and filled grains and increased the grain yield of rice over the split application of prilled urea by 0.43 and 0.3 t ha^{-1} and basal application of large granular urea by 0.73 and 0.64 t ha^{-1} respectively.

Department of Agricultural Extension conducted 432 demonstrations in 72 Upazilla as of 31 districts in Bangladesh of' *boro* rice. It was reported that USG plots, on an average, produced nearly 5 percent higher yields than the PU treated plots while applying 30-40% less urea in the form of USG (Islam and Black, 1998).

Singh and Singh (1997) conducted a field experiment in 1987 in Uttar Pradesh, India, dwarf rice cv. Jaya was given 90 or 120 kg N ha^{-1} as urea super granules, large granular urea or neem cake coated urea. N was applied basally, or in 2 equal splits (basally and panicle initiation). They found that grain yield was highest with 120 kg N (4.65 t ha^{-1}), was not affected by N source and was higher with split application.

Kumar *et al.* (1996) reported that application of USG in the sub soil gave 22% higher grain yield than control.

Rashid *et al.* (1996) conducted field experiments in two locations of Gazipur district to determine the nitrogen use efficiency of urea supergranules (USG) and prilled urea (PU) in irrigated rice cultivation. It was observed that 87 kg N ha^{-1} from USG produced the highest grain yield. However, 58 kg N ha^{-1} from USG and 87 kg N ha^{-1} from PU produced statistically similar grain yield to that of 87 kg ha^{-1} from USG.

2.2 Effect of phosphorus

The amount of P absorbed by hybrid rice during the middle growth stage was over half of the total P absorbed during the whole growth period. However, less P was supplied by soil at the middle growth stage. Phosphorus application resulted in normal growth, early ripening and increased yield. The contents of protein and nitrogen in rice leaves decreased when insufficient P was applied. P enhanced the photosynthetic efficiency of leaves, increased the grain yield and shortened the growth period of rice. It is suggested that P application could enhance the absorption and use of nitrogen and potassium by hybrid rice (Liu, 1996)

2.2.1Effect on growth character

2.2.1.1 Plant height

A field experiment was conducted by Alam *et al.* (2009a) at the Agronomic field of the Sher-e-Bangla Agricultural University to study the relative performance of inbreed and hybrid rice varieties at different levels of P. Three varieties of inbreed and hybrid (BRRI dhan 48, Aloron and Hira 2) and five levels of P (0, 24, 48, 72 and 96 kg P ha^{-1}) were used as treatment. They reported that plant height and growth rate varied significantly due to variation of P and tallest plant was obtained with 96 kg P ha^{-1}.

A field experiment was conducted by Alvi *et al.* (2004) to evaluate how much P should be applied to the rice and wheat crops under rice-wheat cropping system. Nitrogen and potassium were applied uniformly to all the plots at the rate of 120 and 60 kg ha^{-1} respectively. They reported that plant height was influenced significantly by the application of P.

Fageria and Baligar (1997) carried out an experiment to evaluate on the growth and P use efficiency of 20 upland rice cultivars at low (0 mg P kg^{-1}), medium (75 mg P kg^{-1}) and high (150 mg P kg^{-1}) levels of applied P on an Oxisol. Plant height was influenced significantly by the application of P.

2.2.1.2 Tillering pattern

Alam *et al.* (2009b) reported that tiller production differed significantly with the application of P fetrilizer and 72 kg P ha^{-1} showed to produce better tiller production and fertility.

2.2.1.3 Leaf area index and total dry matter production

Alam *et al.* (2009c) found that dry matter partitioning in different part plants varied significantly due to variation of P.

The agronomic efficiency of four phosphate sources (tripol superphate, ordinary Yoorin thermophosp hate, coarse of yoorin thermophosphate and North Carolina phosphate rock) were evaluated by Brasil *et al.* (2002). The soils received three rates of phosphorus (40, 80 and 120 mg P kg^{-1} of soil) plus the control treatment. The results showed the highest dry matter was obtained in soils fertilized with triple superphote.

2.2.2 Yield contributing character

Alam *et al.* (2009d) suggested that filled grain $panicle^{-1}$, unfilled grain $panicle^{-1}$, spikelet sterility, 1000 grain weight had a significant effect with the application of P fertilizer.

Shar and Burbey (2003) conducted a field experiment at farmer fields in dry season, from June to September 2001 with six NPK compound dosages (0, 50, 100, 150, 200 and 250 kg NPK ha^{-1}). Results showed that increasing rate of NPK compound significantly affected the grain number $panicle^{-1}$, unfilled grain percentages, 1000 grain weight and grain yield. The highest grain yield was found by appling 100 kg Urea + 250 kg NPK compound, following by 82.5 kg N + 37.5 kg P_2O_5 ha^{-1}+ 37.5 kg K_2O ha^{-1}.

Mondal *et al.* (2003) conducted a field experiment to investigate the effect of P application on rice cv. IET-5656- lathyrus cv. The treatments comprised 4 fertilizer management levels, i.e. fertilizer application as per farmers practice (40:20:20 kg N: P_2O_5:K_2O ha^{-1}) to rice and no fertilizer application to lathyrus (T_1); 100% of recommended dose of fertilizer (RDF) both rice and lathyrus (T_2); 100% of RDF to rice + recommended dose of P for lathyrus to rice (T_3) and RDF for lathyrus + recommended dose of P for rice to lathyrus at sowing (T_4). The RDF for rice was 80,:40:40: kg N: P_2O_5:K_2O ha^{-1} and that for lathyrus was 10:20:20 kg N: P_2O_5:K_2O ha^{-1}. They reported that highest number of effective tiller m^{-2} (425.0), number grains $panicle^{-1}$ (92.8) of rice were obtained from T_3 treatment.

In pot trials by Jiang *et al*. (1999) on whitish lacustrine soil, rice was given 0, 2, 4, 6 and 8 kg P_2O_5 mu^{-1}. The total number of panicles and ^{1} grain number $panicle^{-1}$ increased with up to 6 kg P_2O_5 mu^{-1}.

2.2.3 Spikelet sterility

Shah (2002) examined the P deficiency in control plots caused stunted growth with limited tillers and decreased filled spikelet percentage $panicle^{-1}$.

Ortega and Rojas (1999) reported that the P application decreased floret sterility.

2.2.4 Grain and straw yield

A field experiment was conducted by Dwivedi *et al*. (2006) in Uttar Pradesh, India in a silt loam soil to evaluate the effect of nitrogen, phosphorous and potassium levels on growth yield and quality (protein) of hybrid rice (*Oryza sativa*). Optimum nitrogen level was found to be 184.07 kg $ha^{-1.}$ In case of phosphorus and potassium, higher doses each of 80 kg ha^{-1} P_2O_5 and K_2O were found to be better to obtain higher production and good quality (protein) of hybrid rice. The maximum grain yield was recorded with 200 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 80 kg K_2O ha^{-1}.

A field experiment was carried out with rice cv. Jia-9312 by Iqbal (2004) in China, involving P at 0, 40 and 60 kg ha^{-1} under irrigated conditions. He stated that a positive effect on rice biomass and grain yield for P application was observed which varied from 5.8 to 7.8 t ha^{-1}.

Saiti *et al*. (2005) conducted an experiment to evaluate three traditional and three improved cultivars which were grown under four fertilizer treatments: no added fertilizer, nitrogen only (90 kg N ha^{-1}), phosphate only (50 kg P ha^{-1}), and N and P (NP) at three locations. Applying only P gave no effect on grain yield, and applying P with N increased grain yield only by 0.5 t ha^{-1} over N application alone on average over all cultivars at all locations.

Alvi *et al.* (2004) reported that paddy grain and straw yields were influenced significantly by the application of P. Application of 50 kg P_2O_5 gave the higher yield following by 100 kg P_2O_5 ha^{-1}.

Ravi *et al*. (2000) conducted an experiment to study on the effects of single superphosphate (SSP), monammonium phosphate (MAP), Maton rock phosphate (MRP), Gapsaphos, North Carolina rock phosphate, Jordan phosphate rock (JPR) A and B, and compactions of JPR A or B with SSP, MAP or MAP + S on the yield of rice and cowpea in rice-cowpea and rice-rice cropping systems. Grain (5921.02 kg ha^{-1}) and pod yield (1638.88 kg ha^{-1}) for the rice-cowpea cropping system and the respective values for the rice-rice cropping system (4216.67 and 4308.77 kg ha^{-1}) were highest with application of JPR (A) + MAP + S (compacted).

Kendaragama *et al.* (2003) conducted an experiment to investigate the seasonal and long- term influence of rice crop on the availability of soil P in relation to five rates of triple super phosphate application (0, 25, 75 and 100 kg P_2O_5 ha^{-1}) in well drained, imperfectly drained and poorly drained soil. This study indicates that practice of correct P supply is needed for sustaining available P status in soil and crop yield although rice does not immediately respond for irregularities phosphate fertilizer application.

Field experiment was conducted by Rao (2003) in India to determine the utilization pattern of phosphorus rates (30, 60 and 90 kg ha^{-1}) and sources (ammonium polyphosphate, urea nitric phosphate and diammonium phosphate) in rice crop in terms of apparent recovery factor, physiological and agronomic efficiency. He stated that 60 kg P ha^{-1} gave the highest agronomic efficiency when P was applied in the form of ammonium polyphosphate following by urea nitric phosphate and diammonium phosphate and the lowest term P rates.

Sing (2003) conducted a field experiment under rainfed condition in Jharkhand, India during to establish the relationships between plant P and grain yield of upland rice cv. Kalinga III grown on red upland soils. He reported that rice yield varied significantly due to P fertilizer.

Nadeem and Ibrahim (2002) carried out a study to determine the P requirement of rice crop grown after wheat, under submearsed condition. Rice crop was 100 kg P_2O_5 and 120 kg N ha^{-1} and highest paddy yield was obtained from the treatment where 37.5 kg (50%) P was applied. It showed that when wheat received its recommended dose of P then for rice only 50% of the recommended rate (75%) is enough to achieve the optimum yield of rice.

Zubaida and Munir (2002) conducted an experiment on phosphorus fertilizer on rice. They found that phosphorus application by P-starter (20 kg SP36 ha^{-1}) is more economical and more benefit over phosphorus application of 100 kg SP36 ha^{-1} and reduce fertilizer application 80 kg SP36 ha^{-1} and gave yield of paddy rice 4.236 and 4.320 t ha^{-1} respectively.

Lal *et al.* (2002) conducted a field experiment to study the individual and interactive effects of P (0, 11, 22, and 33 kg ha^{-1}) and Zn (0, 6 and 12 kg ha^{-1}) on the yield and P uptake of lowland rice. They reported that maximum grain yield (33.35 q ha^{-1}) and P uptake (10.06 kg ha^{-1}) were observed with the combined application of 33 kg P and 12 kg Zn ha^{-1}. Available P in soil samples after harvest increased considerably with increasing rates of P and Zn application.

Annadurai and Palaniappan (1998) in afield trial India in monsoon season, rice was given 0, 9.5, 19 or 38 kg P_2O_5 ha^{-1} with or without spraying 2% diammonium phosphate(DAP) at 2-3 growth stages. Grain yield increased significantly with up to 19 kg P_2O_5 ha^{-1} and was increased by DAP application with no significantly difference between treatment schedule.

Rao and Shukla (1997) conducted a field trial with rice cv. Sarjoo 52 grown with given 13, 26 or 39 kg P ha^{-1} as ammonium polyphosphate, urea nitric phosphate or diammonium phosphate, in combination with 15, 30 or 45 kg $ZnSO_4$ ha^{-1}. They stated that grain yield in both years increased with increasing P rate also with 30 kg $ZnSO_4$ ha^{-1}. Yield was highest when P was applied as applied as ammonium polyphasphate.

Chen *et al*. (1997) conducted a field experiment at the Rice Research Institute of Yunnan Agricultural University, on soils low in P and Zn and rice cultivers- Xunza 29, hexi 35 and Yungeng 34 were given 0 or 5 kg Zn ha^{-1} and 60, 150 or 200 kg P ha^{-1}. Application of Zn and P significantly increased yield.

2.3 Interaction effect of nitrogen and phosphorus

2.3.1 Effect on growth characters

2.3.1.1 Plant height

Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. He found that increased fertilizer dose of NPK increase Plant height.

Saha *et al.* (2004) conducted a field experiment on *boro* season and found that plant height significantly increased with the increased level of different NPK fertilizer model.

Singh *et al.* (2003) reported that crop growth rate, such as plant height, dry mater production averaged across treatments, was highest at 45-60 days after transplanting of rice and significantly influence by NPK fertilizers.

2.3.1.2 Tillering pattern

Ndaeyo *et al.* (2008) conducted an experiment in Nigeria with five rice varieties (WAB340- 8-8-2HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224-8-HB, WAB189-B-B-B-8-HB) and four rates of NPK (15:15:15) fertilizer (0, 200, 400 and 600 kg ha^{-1}). The results showed that 600 kg ha^{-1} NPK (15:15:15) fertilizer rate significantly increased tillers per plant.

2.3.1.3 Total dry matter production

Hasanuzz*aman et al.* (2010) noted that total dry weight of plant increased with the increased different level of fertilizer and poultry manure @ 4 t ha-1 + N-40, P-6, K-36, S-10 kg ha^{-1} i.e. 50% NPK gave the higher dry matter production.

Singh *et al.* (2003) also reported that crop growth rate and relative growth rate such as total dry matter production was significantly influenced by NPK.

2.3.2 Effect on yield contributing characters

2.3.2.1 Effective tillers $hill^{-1}$

Venkateswarlu and Singh (1980) observed higher grain yield with 120 kg N + 60 kg P_2O_5 + 45 kg K_2O ha^{-1} followed by 80 kg N + 40 kg P_2O_5 + 30 kg K_2O ha^{-1}. Yield attributes like number of effective tillers m^{-2}, panicle weight, grains panicle^{-1} and test weight were increased with increase in the fertilizer level.

Halder *et al.* (2000) reported that the number of panicles per plant increased with increase in NPK rates.

2.3.2.2 Panicle length

Islam *et al.* (2008) found that panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, filled grain percentage, influenced significantly due to application of different rates of NPK nutrients.

Asif *et al.* (2000) reported that NPK levels significantly increase the panicle length, number of primary and secondary branches panicle^{-1} when NPK fertilizer applied in 180-90-90 kg ha^{-1} this might be attributed to the adequate supply of NPK.

2.3.2.3 Filled grains panicle^{-1} and unfilled grains panicle^{-1}

Saha *et al.* (2004) conducted an experiment to create and compare a suitable fertilizer recommendation model for lowland rice. Five different fertilizer recommendation models were tested and compared with one check plot. Results show that the application of different packages estimated by different fertilizer models significantly influence panicle length, panicle numbers, spikelet number per panicle, total grains panicle^{-1}, number of filled grain and unfilled grain per panicle. The combination of NPK that gives the height result was 120-13-70-20 kg ha^{-1} NPKS.

2.3.2.4 1000 grain weight

Ndaeyo *et al.* (2008) also reported that number of spikelet per plant was significantly influenced by increase in NPK fertilizer rates. The number of panicles per plant across the rice cultivars showed that it ranged from 15.26 - 17.04 in the 600 kg ha^{-1} plots in 2005 and 15.27 - 16.79 in 2006.

Chandrashekarappa (1985) reported that application of 100 kg N, 100 kg P_2O_5 and 50 kg K_2O ha^{-1} gave the highest grain yield. This was on par with 100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1}. The increase in yield was due to increased dry matter production, plant height, leaf area index, leaf area duration, number of tillers $hill^{-1}$ and to some extent panicle length and 1000 grain weight.

Sikdar and Gupta (1979) observed that spikelet sterility was higher at 100 kg N + 50 kg P_2O_5 + 50 kg K_2O ha^{-1} as compared to 50 kg N + 25 kg P_2O_5 + 25 kg K_2O ha^{-1}. But, the spikelets $panicle^{-1}$, grain yield and to some extent 1000 grain weight were higher with higher dose of fertilizers.

2.3.3 Effect on grain yield and straw yield

Ali *et al.* (2010) conducted an experiment and found that integrated plant nutrition system that is 116-33-5-22-0.40-5000 kg ha^{-1} N-P-K-S-Zn-Cow dung for *boro* and 87-16-15-7-0.15 kg ha^{-1} N-P-K-S-Zn for T. *aman* gives the higher yield. The grain yield of *boro* and T. *aman* rice increased 18% and 14%

respectively than the absolute control and total grain yield of rice was increased by about 16%.

Mollah *et al.* (2008) conducted an experiment to determine the optimum fertilizer dose for Mustard - *boro* - T. *aman* rice cropping pattern which enhancing total production and profit. Six different doses of fertilizer were estimated from soil test value, BARC Fertilizer Recommendation Guide' 97 and Farmers practice. They reported that the highest grain yield and gross margin were obtained from soil test base (STB) fertilizer dose that is 122-25-111-19 kg ha^{-1} NPK for *boro* rice and 82-15-70-11 kg ha^{-1} NPK for T. *aman* rice.

Islam *et al.* (2008) conducted an experiment to determine the response and the optimum rate of nutrients (NPK) for Chili- Fallow-T. *aman* cropping pattern. He found that grain yield influenced significantly due to application of different rates of nutrients and 60-19-36 kg ha^{-1} NPK maximized the yield of T. *aman* rice varieties in respect of yield and economics.

Howlader *et al.* (2007) conducted an experiment at farmers' field of Farming System Research and Development (FSRD) site to determine the response and to find out the optimum rate of nutrients (NPK) for Mungbean-T. *aus*-T. *aman* cropping pattern under AEZ-13. The results indicated that fertilizer nutrient dose that maximized yield of T. *aus* and T. *aman* rice were 78-24-15 kg ha^{-1} and 48-13-13 kg ha^{-1} NPK, respectively while 70-19-14 kg ha^{-1} NPK was profitable for T. *aus* rice and 45-11-13 kg ha^{-1} NPK for T. *aman* rice in respect of yield and economics.

Oikeh *et al*. (2006) combination of 60 kg N, 13 kg P and 25 kg K ha^{-1}` (low to moderate input) has proved sufficient to double grain yield to 4 t ha^{-1} as compared to zero fertilizer application. He recommended 120 kg N, 26 kg P and 25 kg K ha^{-1} appropriate for high input farmers which generates 145% more grain yield compared to no NPK fertilizer application.

Yadav and Tripathi (2006) conducted an experiment in India to find out the best fertility levels for different hybrid rice varieties. Three hybrid rice varieties (Pant Shankar Dhan -1, Pro-Agro 6201 and Pro-Agro 6444) and one inbred variety (NDR-359) were tested at four levels of fertility i.e. control 80: 40: 40, 160: 80:80 and 240:120:120 kg NPK ha^{-1}. Paddy varieties (Pro-Agro 6201 and Pro-Agro 6444) being statistically at par with application of 160:80:80 kg NPK ha^{-1}.

Saito *et al*. (2005) conducted an experiment with three traditional and three improved cultivars were grown under four fertilizer treatments *viz.* 0 kg N ha^{-1}, 90 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and NP. They reported applying P with N increased grain yield over N application alone.

Field experiments conducted by Natarajan and Arivazhagan (2005) at an Annamalai University experimental farm (Tamil Nadu, India) on hybrid rice ADTRH-1 revealed that the application of chemical fertilizer at recommended dose (100:50:50 kg NPK) increased the grain yield to 5.98 t ha^{-1}.

Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. He found that increased fertilizer dose of NPK increase grain and straw yield.

A field experiment was carried out by Surajit *et al*. (2004) at West Bengal, India to study the effect of different levels of fertilizers on the growth and yield of hybrid rice. The experiment was laid out with eight treatment combinations consisting of two cultivars, namely, ProAgro 6444 (hybrid) and IET 4786 (HYV); four levels of fertility (0:0:0, 50:25:25, 100:50:50, 150:75:75 kg N, P_2O_5 and K_2O ha^{-1}) in three replicates. They noted that application of 150:75:75 kg N, P_2O_5 and K_2O ha^{-1}gave the highest grain yield of rice compared with other levels of fertility.

A field experiment was conducted by Pawar *et al*. (2003) at different locations in eastern Vidarbha Zone of Maharashtra, India, to work out the fertilizer requirement of hybrid rice in comparison with high yielding varieties. The fertilizer dose of 150:75:75 kg NPK ha^{-1} gave significantly higher grain yield.

Sudha and Chandini (2002) found that when the recommended dose of NPK that is 70:35:35 kg ha^{-1} was applied then the grain and straw yield was 4.269 and 4.652 t ha^{-1} but when the fertilizer dose is increased 25% and 50% then the grain yield and straw yield increased. For 25% increase of fertilizer the grain and straw yield was 4.363 and 4.877 t ha^{-1} and for 50% increase of fertilizer the grain and straw yield was 4.90 and 5.390 t ha^{-1}, respectively.

Haq *et al.* (2002) conducted an experiment with twelve treatments combination of N, P, K, S, Zn and Diazinon. He found all the treatments significantly increase the grain and straw yield of BRRI dhan 30 rice over control. 90 kg N + 50 kg P_2O_5 + 40 kg K_2O + 10 kg S + 4 kg Zn ha^{-1} + diazinon give the height grain and straw yield.

A field experiment was conducted by Bhowmick and Nayak (2000) to study the performance of hybrids (CNHR 2 and CNHR 3) and high-yielding cultivars (IR 36 and IR 64) of rice (Oryza sativa) at 5 levels of NPK fertilizer (0:0:0, 120:60:60, 150:75:75, 180:90:90) + 30 $ZnSO_4$ kg ha^{-1}. Grain and straw yields increased with increasing level of nutrition for hybrids up to a rate of 180:90:90 + 30 $ZnSO_4$ kg ha^{-1}, and for high-yielding cultivars up to 120:60:60.

The experiment was carried out by Brohi *et al*. (1997) to identify the effect of nitrogen and phosphorus on rice. Nitrogen at the rates of 0, 60, 120, 180 and 240 kg ha^{-1} as urea and phosphorus at the rates of 0, 50, 100 and 150 kg P_2O_5 ha^{-1} as triple superphosphate were applied to the soil before sowing. Additionally potassium was applied at 40 kg K_2O ha^{-1} level as K_2SO_4 per pot for normal plant growth. Both nitrogen and phoshorus fertilization have increased the straw and grain yields of rice plant significantly.

Brohi *et al*. (1997) also conducted an experiment to identify the effect of N and P fertilization on the yield and nutrient status of rice crop. They found that interaction effect of N and P for grain and straw was highest with 240 kg N ha^{-1} and 150 kg P_2O_5 ha^{-1}.

From the reviews cited and discussed above, it can be concluded that nitrogen, phosphorus and their interaction play a remarkable role for growth, yield and yield components of hybrid rice when urea supergranule was proved to be superior to prilled urea in rice cultivation.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1 Experimental period

The experiment was conducted during the period from November, 2010 to May, 2011 in *boro* season.

3.2 Site description

The experiment was conducted in the Sher-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28. For better understanding the experimental site is shown in the Map of AEZ of Bangladesh in Appendix I.

3.3 Climate

The experimental area under the sub-tropical climate is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). The weather data during the study period at the experimental site are shown in Appendix II.

3.4 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

3.5 Crop / planting material

Rice variety hybrid heera1 was used as the test crop.

3.5.1 Description of rice cultivars

The variety is grown in *boro* season. The variety is recommended for cultivation in medium high lands and medium low lands where the maximum tidal depths not exclude to 50 cm. This cultivar matures at 140-145 days of planting. It attains a plant height 125-130 cm. The cultivar gives an average yield of 10-12 t ha^{-1}.

3.5.2 Description of the nitrogen

Ordinary or PU and USG were used as the sources of nitrogen fertilizer.

Prilled Urea (PU)

Ordinary or prilled urea is the most common form of urea available in the market. It contains 46% N.

Urea supergranules (USG)

Urea supergranules fertilizer was manufactured from a physical modification of ordinary urea fertilizer. The International Fertilizer Development Centre (IFDC), Muscle Shoals, Alabama 35660, USA, has developed it. Its nature and properties are similar to that of urea. But its granule size is bigger and condensed with some conditions for slow hydrolysis. USG is spherical in shape containing 46% N which is similar to that of PU average diameter of the granule is 11.5 mm. It is not a slow release fertilizer but can be considered as a slowly available N fertilizer. The supergranules are made by compressing prilled or granular urea in small machines with indented pocket rollers that, depending on the size of the pocket, produce individual briquettes varying in weight from 0.9 to 2.7 g.

3.6 Seed collection and sprouting

Seeds of Hybrid heera1 were collected from Supreme Seed Company Ltd. Healthy seeds were selected following standard method. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs.

3.7 Raising of seedlings

A common procedure was followed in raising of seedlings in the seedbed. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.8 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.9 Preparation of experimental land

The experimental field was first opened on 15 December, 2010 with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from the field. The field layout was made on 25 December, 2010 according to design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.10 Fertilizer management

The experimental plots were fertilized with K, Zn and S @ 134.7, 7.5, 60 kg ha^{-1} in the form of muriate of potash (MOP), zinc sulphate and gypsum, respectively (BRRI, 2010) as basal. TSP was given as basal following treatment variable. The USG weighing 2.7 g each were placed at 5-10 cm soil depth at 10 DAT in the center of four hills in alternate rows @ 1 granule in one spot to supply 75 kg N ha^{-1}. Nitrogen in the form of USG and prilled urea (PU) was given following treatment levels. Split application of nitrogen was done only for PU at 10, 35 and 55 DAT.

3.11 Experimental treatments

Treatment was considered of two factors like

Factor A:

Nitrogen Level (N)

1) N_o = 0 kg N ha^{-1}
2) N_1 = 80 kg N ha^{-1}
3) N_2 = Urea super granules (2.7 g) @ 75 kg N ha^{-1}
4) N_3 = 120 kg N ha^{-1}
5) N_4 = 160 kg N ha^{-1}
6) N_5 = 200 kg N ha^{-1}

Factor B:

Phosphorus Level (P)

1) P_0 = 0 kg P_2O_5 ha^{-1}
2) P_1 = 30 kg P_2O_5 ha^{-1}
3) P_2 = 50 kg P_2O_5 ha^{-1}

4) $P_3 = 70$ kg P_2O_5 ha^{-1}

3.12 Experimental design

The experiment was laid out in a split plot design with three replications having urea application in the main plots, phosphorus in the sub plots. There were 24 treatments combinations. The total numbers of unit plots were 72. The size of unit plot was 5 m x 2.5 m = 12.5 m^2. The distances between sub-plot to sub-plot, main plot to main plot and replication to replication were, 0.75, 0.75 and 1.5 m, respectively.

3.13 Uprooting and Transplanting of seedlings

Thirty days old seedlings were uprooted carefully and were kept in soft mud in shade. The seed beds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. Seedlings were then transplanted as per experimental treatment on the well puddled plots on 27 December 2010. In each plot, there were 12 rows, each row containing 33 hills of rice seedlings. There were in total 396 hills in each plot.

3.14 Intercultural operations

3.14.1 Gap filling

After one week of transplanting, a minor gap filling was done where it was necessary using the seedling from the same source.

3.14.2 Weeding

During plant growth period two hand weeding were done, first weeding was done at 23 DAT (Days after transplanting) followed by second weeding at 38 DAT.

3.14.3 Application of irrigation water

Irrigation water was added to each plot according to the critical stage. Irrigation was done up to 5 cm.

3.14.4 Method of water application

The experimental plots were irrigated through irrigation channels. Centimeter marked sticks were installed in each plot which were used to measure depth of irrigation water.

3.14.5 Plant protection measures

Plants were infested with rice stem borer and leaf hopper to some extent which was successfully controlled by applying two times of Diazinone 60 EC on 15 February and 16 March, 2011. Crop was protected from birds during the grain filling period.

3.15 General observation of the experimental field

The field was investigated time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest should be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller was observed during tillering stage. But any bacterial and fungal disease was not observed. The flowering was not uniform. Lodging did not occur in during the heading stage due to heavy rainfall with gusty winds.

3.16 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting was done on 11 May, 2011. An area of 3 m^2 was harvested from centre of each plot avoiding the border effect. The crop of each plot was collected and harvested separately, bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.17 Recording of data

A. Crop growth characters

Plant height (cm) at 15 days interval started from 15 DAT to harvest

Tillers $hill^{-1}$(No.) at 15 days interval started from 45 DAT to harvest

Leaf area index at 15 days interval started from 15 DAT to harvest

Dry matter weight of plant at 30 days interval started from 30 DAT to harvest

B. Yield contributing characters

Effective tillers $hill^{-1}$ (No.)

Fertile spikelets (filled grains) $panicle^{-1}$ (No.)

Sterile spikelets (unfilled grains) $panicle^{-1}$ (No.)

Weight of 1000 grain (g)

C. Yield

Grain yield (t ha^{-1})

Straw yield (t ha^{-1})

Biological yield (t ha^{-1})

Harvest index (%)

3.18 Experimental measurements

The necessary data on agronomic characters were collected from randomly ten selected hills from each plot in field and at harvest.

Plant height (cm)

The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of panicle after heading.

Tillers hill^{-1} (No.)

Tillers hill^{-1} were counted and averaged as number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

Leaf area index (LAI)

Leaf area index were estimated measuring the length and width of leaf and multiplying by a factor of 0.75 followed by Yoshida (1981).

Dry matter weight of plant

The sub-samples of 5 hills plot^{-1} uprooting from 2nd line were oven dried until a constant level from which the weight of total dry matter were recorded.

Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 panicles.

Effective tillers hill^{-1} (No.)

The panicles which had at least one grain was considered as effective tiller. The effective tillers from ten hills were counted and averaged to hill^{-1}basis.

Noneffective tillers hill^{-1} (No.)

The tiller having no panicle was regarded as ineffective tiller. The non-effective tillers from ten hills were counted and mean was expressed on hill^{-1}basis.

Fertile spikelets (filled grains) panicle^{-1}

Spikelet was considered to be fertile if any kernel was present there in. The number of total fertile spikelets present on each panicle was recorded.

Sterile spikelets (unfilled grains) panicle^{-1}

Sterile spikelet means the absence of any kernel inside in and such spikelets present on each panicle were counted.

Total spikelets panicle^{-1}

The number of fertile spikelets panicle^{-1} plus the number of sterile spikelets panicle^{-1} gave the total number of spikelets panicle^{-1}.

Weight of 1000-grain

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

Grain yield

Grain yield was determined from the central 3 m^2 areas of each plot were sun dried, cleaned, weighed carefully and adjusted at 12% moisture level. Weight of grains of each plot was converted into t ha^{-1}. Grain moisture content was measured by using a digital moisture meter.

Straw yield

Straw yield was determined from the central 3 m^2 of the plot. After threshing, the sub-sample was sun dried, cleaned, weighed separately and finally converted to t ha^{-1}.

Biological yield

The biological yield was calculated with the following formula-

Biological yield= Grain yield + Straw yield

Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with following formula (Gardner *et al*., 1985).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.19 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the IRRISTAT (Version 4.0, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by Duncan's Multiple Range Test (DMRT).

Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

The experiment was conducted to investigate the influence of nitrogen and phosphorus levels on the growth and yield of hybrid Heera1. This chapter comprised with presentation and discussion of the results obtained from the study. Treatments effect of nitrogen and phosphorus on all the studied parameters have been presented in Figure 1 to Figure 16 and interaction effect of nitrogen and phosphors in Table 1 to Table 6. Summary of mean square values of different parameters are also given in Appendices IV to IX.

4.1 Crop growth characters

4.1.1 Plant height

4.1.1.1 Effect of nitrogen

Effect of N levels showed a significant variation on plant height for all growth stages (Figure 1 and Appendix IV). Regardless of treatment differences, plant height increased progressively up to maturity. At 15 DAT maximum plant height (17.83 cm) was observed with N_3 (120 kg N ha^{-1}) and minimum was obtained with control which was significantly identical with N_0, N_1, N_2, N_4 and N_5. At 30 DAT, tallest plant (17.94 cm) was found with N_3 (120 kg N ha^{-1}) which was followed by N_2 (USG @ 75 kg N ha^{-1}), N_5 (200 kg N ha^{-1}) and N_4 (160 kg N ha^{-1}) and shortest plant with N_0 (0 kg N ha^{-1}). At 45 DAT, highest plant height (26.58 cm) was obtained with N_5 (200 kg N ha^{-1}) which was statistically at par with N_4 (160 kg N ha^{-1}) and N_3 (120 kg N ha^{-1}) and shortest plant with N_0 (0 kg N ha^{-1}). At 60 DAT, highest plant height (44.30 cm) was obtained with N_2 (USG @ 75 kg N ha^{-1}) which was similar with N_5 (160 kg N ha^{-1}) and N_4 (120 kg N ha^{-1}) and shortest plant (37.22 cm) with N_0 (0 kg N ha^{-1}). The similar trend was obtained at 75 DAT, 90 DAT, 105 DAT and at harvesting. It was observed that USG influenced plant after lag phase (15 DAT- 45 DAT) and proved superior to PU upto harvest. It might be due to continuous availability of N from the deep placed USG that released N slowly and it enhanced growth to crop more than urea. The results are in agreement with those of Singh and Singh (1986) who reported that USG produced taller plants than prilled urea when applied @ 27 to 87 kg N ha^{-1}.

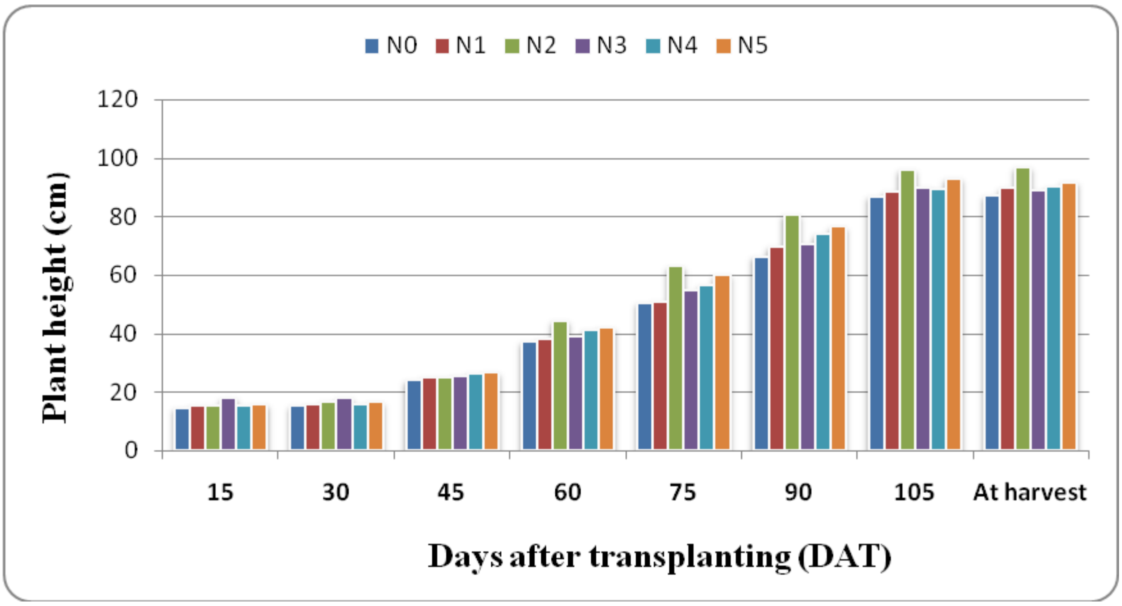

Figure 1. Effect of nitrogen on plant height of hybrid Heera1 at different days (SE = 0.66, 0.68, 0.66, 1.11, 1.05, 1.36, 1.08, 1.06 at 15, 30, 45, 60, 75, 90, 105 and harvest, respectively)

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}

4.1.1.2 Effect of phosphorus

Significant variation in plant height was not observed due to different levels of phosphorus at all growth stages (Figure 2 and Appendix IV). At 15 DAT, 45 DAT and harvesting numerically maximum height was obtained with 50 kg P_2O_5 ha^{-1} and minimum plant height was observed with control treatment. But at 30 DAT numerically highest plant height was obtained with 30 kg P_2O_5 and lowest plant height was observed with control treatment. At 60 DAT, 75 DAT, 90 DAT and 105 DAT tallest plants was found with 70 kg P_2O_5 ha^{-1} and shortest with control treatment. Morgan (1997) reported the similar effect of P on the plant height. De Datta (1981) reported stunted growth due to deficiency of phosphorus.

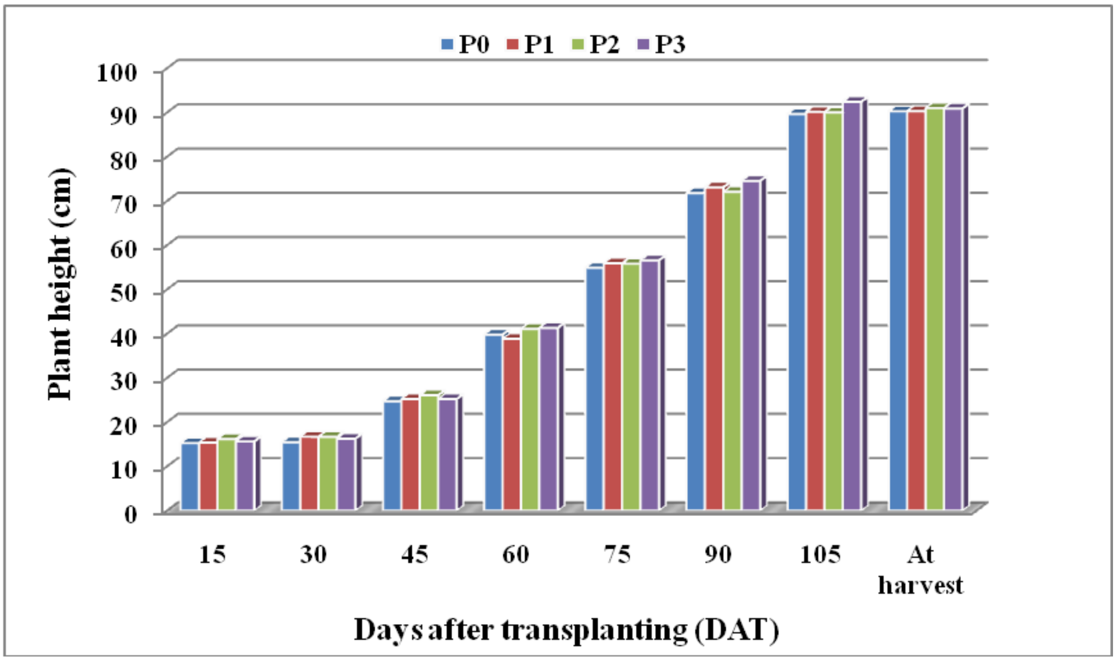

Figure 2. Effect of phosphorus on plant height (cm) of hybrid Heera1 at different days (SE = 0.54, 0.55, 0.54, 0.90, 0.86, 1.11, 0.88, 0.87 at 15, 30, 45, 60, 75, 90, 105 and harvest, respectively)

P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.1.1.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus levels on plant height was statistically significant except 30 DAT (Table 1 and appendix IV). At 15 DAT, the tallest plant (18.97 cm) was recorded by the interaction of N_3P_2 (120 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) and at par with N_5P_3 (200 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}), N_3P_3 (120 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) and N_3P_1 (120 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}). The lowest plant height (12.70 cm) was observed from the treatment combination of N_0P_1 (0 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}). At 45 DAT, the tallest plant (28.54 cm) was resulted by the interaction of N_5P_3 (200 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) and similar with N_4P_1, N_5P_2, $N_3P_{3,}$ N_3P_2 where the lowest plant height (21.04 cm) was observed from the treatment combination of N_0P_3. At 60 DAT, the tallest plant (46.03 cm) was observed by the interaction of N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) and similar with N_2P_2, N_5P_3 where the lowest plant height (32.63 cm) was observed from the treatment combination of N_0P_0. At 75 DAT, the tallest plant (cm) was recorded by the interaction of N_2P_1 (USG kg 75 N ha^{-1} and 30 kg P_2O_5 ha^{-1}) which was statistically followed by N_2P_3, N_5P_3, N_5P_3 where the lowest plant height (48.12 cm) was observed from the treatment combination of N_0P_0. Similar trend was found at 90 DAT. At 105 DAT, the tallest plant (97.48 cm) was recorded by the interaction of N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) which was statistically identical with N_2P_2, N_5P_3 where the lowest plant height (84.26 cm) was observed from the treatment combination of N_0P_0. At harvesting, the tallest plant (98.72 cm) was obtained by the interaction of N_2P_3

Table 1. Interaction effect of nitrogen and phosphorus on plant height (cm) of hybrid Heera1 at different days after transplanting

Treatment	Days after transplanting							
	15	30	45	60	75	90	105	At harvest
N_0P_0	14.61 a-c	15.54 a	24.72 a-c	32.63 e	48.12 g	63.52 g	84.26f	85.94e
N_0P_1	14.65 a-c	14.44 a	24.00 a-c	38.50 a-e	52.81 d-g	68.83 c-g	89.00c-f	89.07c-e
N_0P_2	15.04 a-c	15.48 a	26.00 ab	39.50 a-e	52.22 e-g	65.67fg	86.53d-f	86.98de
N_0P_3	13.90 bc	15.90 a	21.04 c	38.26 b-e	48.52 g	67.00e-g	87.82d-f	86.09e
N_1P_0	16.46 a-c	14.87 a	24.31a-c	37.02 c-e	48.03 g	65.22eg	87.62d-f	89.62c-e
N_1P_1	14.79 a-c	17.50 a	25.46 a-c	37.50 b-e	51.69 e-g	71.89b-g	88.58c-f	89.90c-e
N_1P_2	16.76 a-c	13.47 a	25.61 ab	40.41 a-d	51.16 fg	71.00b-g	87.88d-f	88.98de
N_1P_3	12.70 c	16.19 a	23.85 bc	36.84 c-e	52.24 e-g	70.44b-g	89.67b-f	89.81c-e
N_2P_0	15.59 a-c	15.85 a	26.64 ab	44.45 a-c	63.29 ab	82.33a	95.42a-c	96.37a-c
N_2P_1	14.78 a-c	16.05 a	23.25 bc	41.68 a-d	63.99 a	84.22a	94.00a-d	94.07a-d
N_2P_2	15.13 a-c	18.07 a	24.87 a-c	45.02 ab	61.25 a-c	77.33a-c	96.87ab	97.79ab
N_2P_3	15.34 a-c	17.00 a	24.91 a-c	46.03 a	62.79 a-c	78.33ab	97.48a	98.72a
N_3P_0	16.53 a-c	18.12 a	23.67 bc	36.60 de	53.90 d-g	67.44d-g	89.00c-f	89.41c-e
N_3P_1	17.84 ab	17.87 a	24.27 a-c	37.91 b-e	52.00 e-g	68.67c-g	90.41a-f	87.97de
N_3P_2	18.97 a	17.98 a	26.86 ab	41.47 a-d	56.01 c-f	70.34b-g	89.30c-f	89.15c-e
N_3P_3	17.97 ab	17.80 a	26.99 ab	40.28 a-d	56.30 b-f	75.67a-e	90.29a-f	88.99de
N_4P_0	15.65 a-c	14.33 a	25.35 a-c	44.11 a-d	56.27 b-f	75.33a-e	89.13c-f	92.89a-e
N_4P_1	14.60 a-c	16.46 a	27.66 ab	39.03 a-e	58.66 a-e	73.11b-f	89.05c-f	91.00b-e
N_4P_2	15.04 a-c	17.55 a	25.91 ab	39.91 a-e	52.69 e-g	70.67b-g	85.65ef	86.05e
N_4P_3	15.63 a-c	15.14 a	26.17 ab	41.97 a-d	57.79 a-f	76.33a-d	93.83a-d	90.00c-e
N_5P_0	12.90 c	14.17 a	23.69 bc	44.00 a-d	59.78 a-d	76.78a-c	92.77a-e	91.84a-e
N_5P_1	15.70 a-c	18.03 a	26.76 ab	38.47 a-e	56.39 b-f	71.89b-g	89.83b-f	90.08c-e
N_5P_2	15.88 a-c	17.63 a	27.32 ab	40.15 a-e	61.67 a-c	77.56a-c	93.84a-d	92.78a-e
N_5P_3	18.36 ab	15.70 a	28.54 a	44.68 ab	61.91 a-c	79.44ab	95.57a-c	91.97a-e
SE	**1.32**	**1.35**	**1.32**	**2.21**	**2.09**	**2.71**	**2.17**	**2.13**
CV (%)	**14.69**	**14.38**	**9.02**	**9.50**	**6.51**	**6.45**	**4.14**	**4.06**

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1},
P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

(USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) which was statistically at par with N_2P_2, N_2P_1 where the lowest plant height (85.94 cm) was observed from the treatment combination of N_0P_0. Saito *et al*. (2005) conducted an experiment and reported that application of 90 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} gave highest plant height.

4.1.2 Total tiller hill^{-1}

4.1.2.1 Effect of nitrogen

Tiller number hill^{-1} was significantly influenced by the nitrogen levels at all growth stages except 45 DAT (Figure 3 and Appendix V). Tiller number hill^{-1} increased with age reaching a peak at 75 DAT and there after decline. No tiller was observed at 15 DAT and 30 DAT due to extremely low temperature. At 45 DAT, numerically maximum tiller number hill^{-1} (4.53) was observed with USG @ 75 kg N ha^{-1} (N_2) and minimum (3.89) with control treatment. Application of USG @ 75 kg N ha^{-1} (N_2) produced maximum tiller hill^{-1} and followed by 200 kg N ha^{-1} (N_5), 160 kg N ha^{-1} (N_4), 120 kg N ha^{-1} (N_3), 80 kg N ha^{-1} (N_1) and control irrespective of growth stage. At 60 DAT, highest number of tiller hill^{-1} (9.69) was observed with USG @ 75 kg N ha^{-1} (N_2) which was statistically at par with 200 kg N ha^{-1} (N_5) (8.99) and lowest number of tillers hill^{-1} (6.53) was obtained with N_0. The second highest number of tiller (7.97) was found with 160 kg N ha^{-1} (N_4). At 75 DAT, maximum number of tiller hill^{-1} (20.11) was obtained with USG @ 75 kg N ha^{-1} (N_2) and minimum (10.33) with N_0.The second highest was obtained with 160 kg N ha^{-1} (N_4). Similar trend was noticed at 90 DAT, 105 DAT and at harvest. The improvement in the formation of tillers with N application in the present experiment might be due to increase of nitrogen availability which enhanced tillering. Increased number of tillers in USG than others might be due to uniform N supply through USG. Mirzeo and Reddy (1989) and Singh and Singh (1986), also reported that USG produced highest number of tillers @ 87 kg N ha^{-1}. Kabir *et al*. (2009) and Masum *et al*. (2008) reported that highest number of tiller $hill^{-1}$ was found from full doses of USG @ 58 kg N ha^{-1}. Hasanuzzaman *et al*. (2009) reported that deep placement of USG @ 75 kg N ha^{-1} showed highest number of tillers might be due to little loss of N from soil and slowly releasing process. Hamidullah *et al*. (2006) found that tiller number increased with increasing N and 120 and 160 kg N ha^{-1} produced statistically similar tiller $hill^{-1}$. On the other hand Peng *et al.* (1996) and Schnier *et al.* (1990) reported that N supply controlled the tiller production of rice plant unless other factors such as spacing or light became limiting.

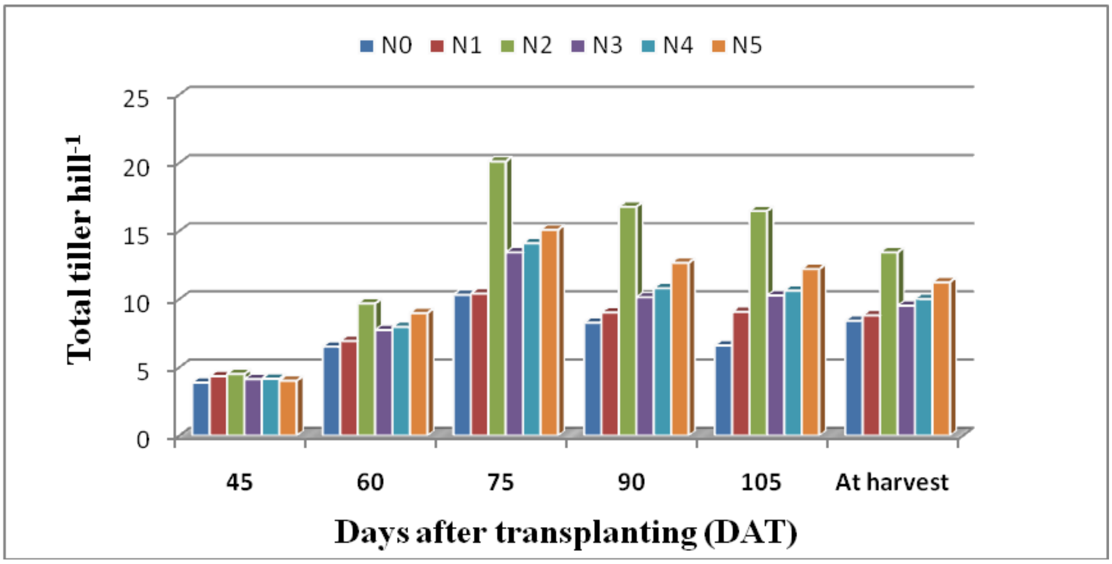

Figure 3. Effect of nitrogen on tiller hill^{-1} of hybrid Heera1 at different days (SE = 0.24, 0.49, 0.77, 0.58, 0.53, 0.53 at 45, 60, 75, 90, 105 and at harvest, respectively)

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}

4.1.2.2 Effect of phosphorus

Significant variation in tiller number hill^{-1} was not observed due to different levels of phosphorus at all growth stages (Figure 4 and Appendix V). At 15 DAT, 30 DAT no tiller was found might be due to extremely low temperature during the month of January. Tiller number hill^{-1} increased with age reaching a peak at 75 DAT and there after decline. At 45 DAT and 90 DAT, numerically maximum tiller hill^{-1} was obtained with 70 kg P_2O_5 ha^{-1} and minimum plant height was observed with control treatment. But at 60 DAT, 75 DAT and 105 DAT numerically highest tiller hill^{-1} was obtained with 30 kg P_2O_5 ha^{-1} and lowest tiller hill^{-1} was observed with control treatment. At harvesting time numerically maximum tiller hill^{-1} (10.80) was found with 50 kg P_2O_5 ha^{-1} and minimum (9.43) with control treatment. De Datta (1981) reported that increase in tiller due to application of P.

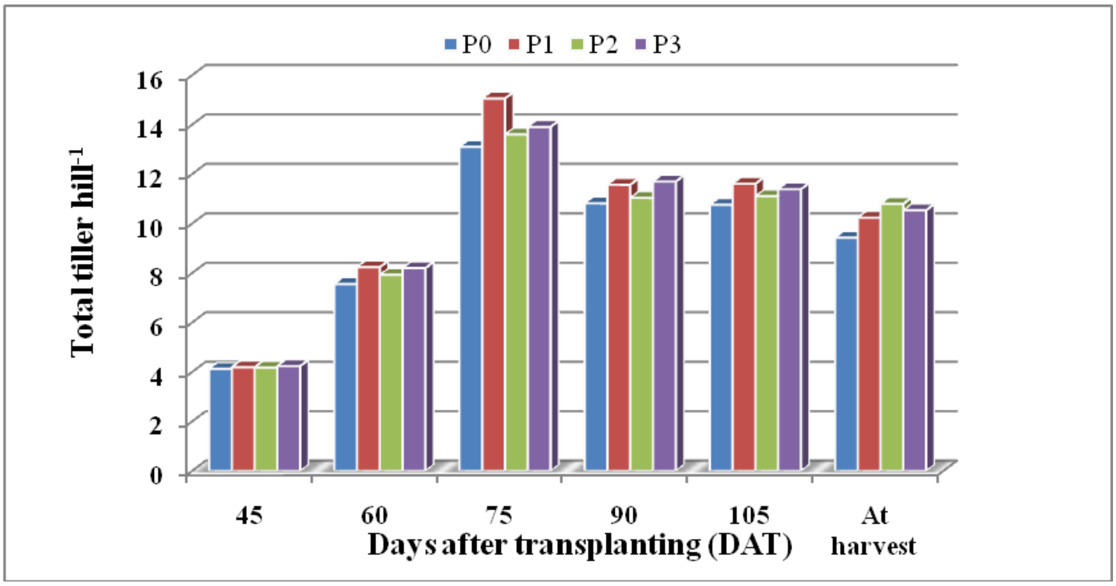

Figure 4. Effect of phosphorus on tiller hill^{-1} of hybrid Heera1 at different days (SE = 0.19, 0.39, 0.63, 0.47, 0.45, 0.43 at 45, 60, 75, 90, 105 and harvest, respectively)

P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.1.2.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus levels showed significant influence on the tiller dynamic of the hybrid rice (Table 2 and appendix V). The plant seen to has a lag phase in early stage 15 and 30 DAT and there after plants had sharp rise in the tiller number continued till 75 DAT. The highest tiller (4.89) at 45 DAT was achieved by N_4P_3 (160 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) treatment combination which was followed by N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (4.78), N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (4.67). At 60 DAT, maximum tiller (10.67) was found with N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) which was statistically at par with N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (10.11) and minimum tiller (5.44) with control. At 75 DAT, highest tiller (22.67) was found with N_2P_2 (USG @ 75 kg N ha^{-1} and 50

Table 2. Interaction effect of nitrogen and phosphorus on tiller $hill^{-1}$ of hybrid Heera1 at different days after transplanting

Treatment	Days after transplanting					
	45	60	75	90	105	At harvest
N_0P_0	2.89 b	5.67 de	9.78 f-h	8.44f-h	8.67 f-h	8.22 f-h
N_0P_1	4.55 a	7.67 a-e	10.67 e-h	7.00 h	7.78 gh	7.44 gh
N_0P_2	4.00 ab	5.45 e	9.66 f-h	7.22 gh	7.44 h	8.89 f-h
N_0P_3	4.11 ab	7.33 a-e	11.22 d-h	10.44 e-h	10.55 d-h	9.11 f-h
N_1P_0	4.33 ab	7.11 b-e	9.00 gh	8.67 f-h	8.57 f-h	7.11 h
N_1P_1	4.44 ab	5.44 e	14.11 b-g	8.22 f-h	8.67 f-h	7.33 gh
N_1P_2	4.22 ab	7.55 a-e	8.11 h	8.11 f-h	8.78 f-h	10.00 d-h
N_1P_3	4.44 ab	7.67 a-e	10.44 e-h	11.11 d-g	10.34 d-h	10.89 a-g
N_2P_0	4.33 ab	9.22 a-c	17.89 a-c	17.78 ab	16.56 ab	12.89 a-e
N_2P_1	4.67 a	10.11 ab	21.22 a	16.11 a-c	16.45 ab	13.11 a-d
N_2P_2	4.33 ab	10.67 a	22.67 a	18.56 a	18.22 a	13.78 a-c
N_2P_3	4.78 a	8.78 a-e	18.67 ab	14.66 b-d	14.67 bc	14.00 ab
N_3P_0	4.78 a	6.11 c-e	13.89 b-g	9.37 f-h	9.89 e-h	8.67 f-h
N_3P_1	3.44ab	8.67 a-e	14.78 b-f	11.67 d-f	11.66 c-f	10.00 d-h
N_3P_2	3.44 ab	8.00 a-e	12.78 c-h	9.89 e-h	10.44 d-h	11.11a-f
N_3P_3	3.89 ab	8.22 a-e	12.33 d-h	9.67 e-h	9.11 f-h	8.33 f-h
N_4P_0	4.44 ab	7.78 a-e	11.89 d-h	9.89 e-h	10.00 e-h	9.44 e-h
N_4P_1	3.78 ab	8.56 a-e	15.11 b-e	11.67 d-f	11.22 d-g	9.33 e-h
N_4P_2	3.56 ab	7.78 a-e	14.67 b-f	10.66 e-h	10.89 d-h	10.67 b-h
N_4P_3	4.89 a	7.78 a-e	14.78 b-f	11.00 d-g	10.44 d-h	10.67 b-h
N_5P_0	4.00 ab	9.44 a-c	16.14 b-d	10.78 e-h	10.89 d-h	10.22 d-h
N_5P_1	4.22 ab	9.00 a-d	14.44 b-f	14.78 b-d	13.89 b-d	14.22 a
N_5P_2	4.54 ab	8.11 a-e	13.78 b-g	11.78 d-f	10.89 d-h	10.33 c-h
N_5P_3	3.33 ab	9.44 a-c	16.00 b-d	13.33 c-e	13.22 b-e	10.22 d-h
SE	**0.48**	**0.97**	**1.55**	**1.15**	**1.07**	**1.06**
CV (%)	**19.81**	**21.15**	**19.26**	**17.71**	**16.47**	**17.85**

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}, P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

kg P_2O_5 ha^{-1}) which was statistically identical with N_2P_1 (21.22), N_2P_3 (18.67). The decreasing trend of tiller production was observed from 90 DAT irrespective of treatment variables. At 90 DAT, maximum tiller (18.56) was found with N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) which was statistically similar with N_2P_1 (16.45) and minimum (7.00) with N_0P_2. Similar trend was found at 105 DAT and harvesting time. In this experiment the total tiller $hill^{-1}$ was found decreased with time. Yoshida (1981) stated that it could be happened due to tiller mortality of rice plants after reproductive stage.

4.1.3 Leaf Area Index (LAI)

4.1.3.1 Effect of nitrogen

Leaf area index (LAI) or the surface area of green leaves produced by rice plants unit $area^{-1}$ of land was taken as an index of leaf area development. The leaf area of plant is one of the major determinants of its growth. LAI was significantly affected by nitrogen treatments observed at 30, 45, 60, 75, 90, 105 DAT and at harvest. There was no statistical difference in the values of LAI observed at 15 DAT (Figure 5 and Appendix VI). Maximum (7.23) LAI was found at 90 DAT due to the effect of USG @ 75 kg N ha^{-1} which was followed by N_5 (200 kg N ha^{-1}). However, after 90 DAT, LAI declined due to senescence of leaves with the progress to maturity. At 30 DAT, maximum LAI (0.15) was found with N_2 (USG @ 75 kg N ha^{-1}) which was followed by N_5 (200 kg N ha^{-1}), N_3 (120 kg N ha^{-1}) and minimum (0.11) with control. At 45 DAT, maximum LAI (0.48) was observed with N_4 (160 kg N ha^{-1}) which was statistically at par with N_3, N_5 and minimum with control. At 60 DAT highest LAI (1.17) was identified with N_5 (200 kg N ha^{-1}) which was statistically identical with N_2 (USG @ 75 kg N ha^{-1}) and lowest was with N_0. At 75 DAT, maximum LAI (3.64) was found with N_2 (USG @ 75 kg N ha^{-1}) which was statistically similar with N_5 (200 kg N ha^{-1}) and minimum was with N_0. Similar trend was found at 105 DAT and at harvest. Masum *et al.* (2008) reported that LAI was significantly higher in USG receiving plants than urea. Gorgy *et al*. (2009) observed higher LAI (7.09) with application of 165 kg N ha^{-1} as three equal splits and Hamidullah *et al*. (2006) found maximum LAI with 160 kg N ha^{-1}. Ali (2005) and Miah *et al.* (2004) reported that LAI was significantly higher in USG receiving plants than urea.

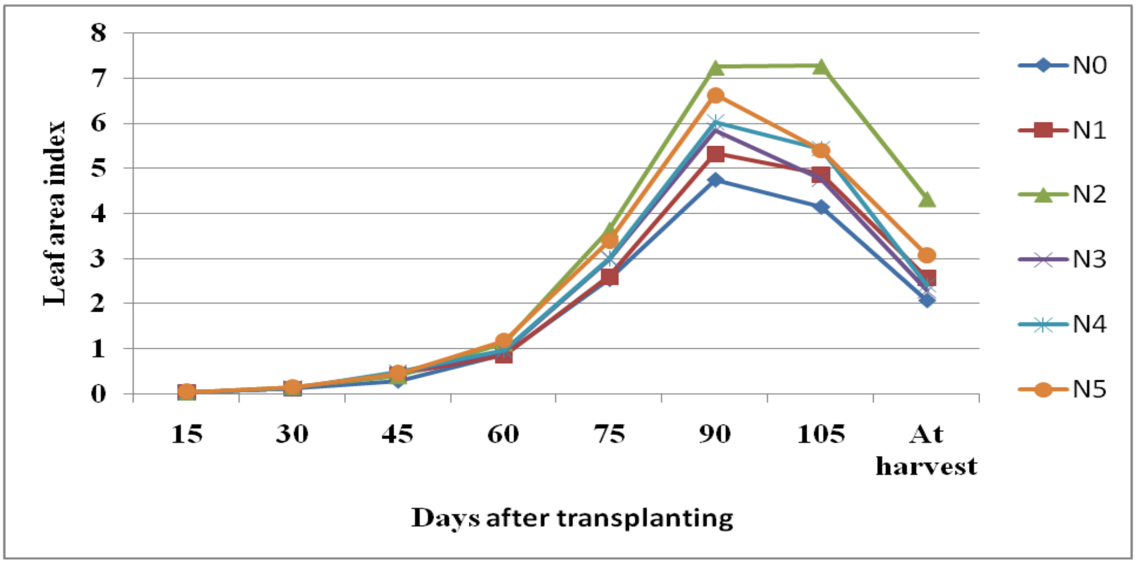

Figure 5.Effect of Nitrogen on leaf area index of hybrid Heera1 at different days (SE = 0.01, 0.01, 0.03, 0.05, 0.06, 0.14, 0.25, 0.30, 0.17 at 15, 30, 45, 60, 75, 90, 105 and harvest, respectively)

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}

4.1.3.2 Effect of phosphorus

There was no significant effect of phosphorus on leaf area index at all growth stages. (Figure 5 and Appendix VI) Leaf area index increased with age reaching a peak at 90 DAT and there after decline. At 15 DAT, numerically higher LAI (0.03) was found with 30 kg P_2O_5 ha^{-1} (P_1) and lowest with P_3 (70 kg P_2O_5 ha^{-1}). But at 30 DAT, numerically maximum LAI (0.13) was observed with 70 kg P_2O_5 ha^{-1} and minimum with P_0. At 45 DAT, numerically highest LAI (0.45) was found with P_3 (70 kg P_2O_5 ha^{-1}) and lowest with P_0. Similar trend was found at 60 DAT. Application of 50 kg P_2O_5 ha^{-1} produced numerically highest LAI (3.05) and lowest (2.99) with P_0 at 75 DAT. Similar trend was also found at 90, 105 DAT. At 90 DAT, numerically highest LAI (6.22) was identified with 50 kg P_2O_5 ha^{-1} which was highest among the all growth stages. Application of 70 kg P_2O_5 ha^{-1} (P_2) produced highest LAI (2.95) and lowest (2.73) at maturity.

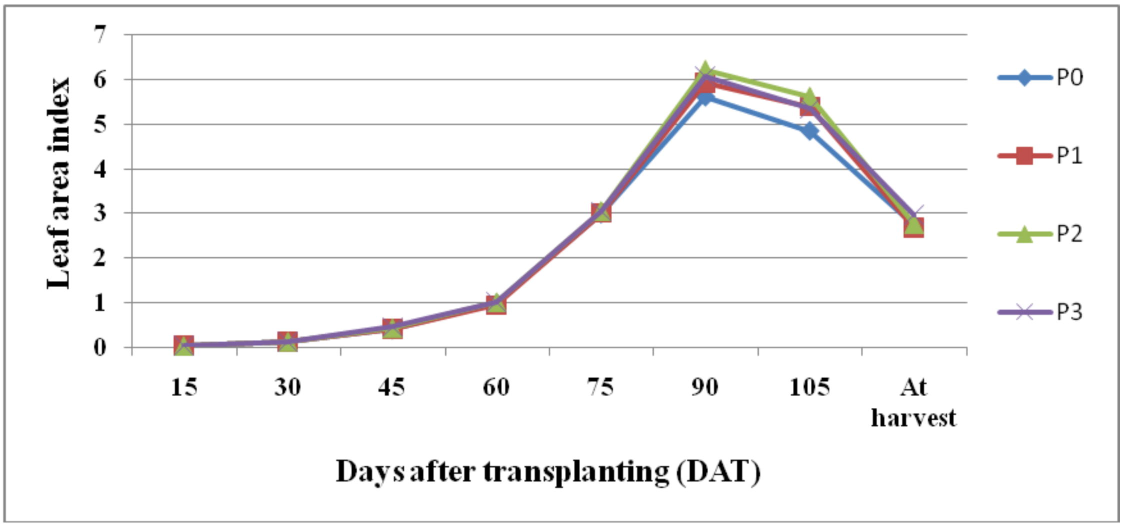

Figure 6. Effect of phosphorus on leaf area index of hybrid Heera1 at different days (SE = 0.01, 0.01, 0.03, 0.02, 0.05, 0.11, 0.21, 0.25, 0.17, 0.14 at 15, 30, 45, 60, 75, 90, 105 and harvest, respectively)

P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.1.3.3 Interaction effect of nitrogen and phosphors

There was no statistically variation in the value of LAI as was observed at 15 DAT but significant at others due to the interaction of nitrogen and phosphorus (Table 3 and appendix VI). At 30 DAT maximum LAI (0.18) was observed with N_5P_3 (200 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) which was statistically at par with N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}), N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}), N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}), N_3P_1 (120 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}), N_3P_2 (120 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) and minimum was with N_0P_0. At 45 DAT maximum LAI (0.57) was observed with N_5P_3 (200 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) which was statistically similar with N_4P_3 (160 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}), N_3P_3 (120 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}), N_3P_2 (120 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}), N_4P_1 (160 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}), N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}), N_5P_2 (200 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}), N_4P_2 (160 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) and minimum was with N_0P_0. At 60 DAT maximum LAI (1.50) was observed with N_5P_3 (200 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) which was statistically at par with N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}), N_5P_1 (200 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) and minimum was with N_0P_0. At 75 DAT maximum LAI (4.04) was observed with N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) which was statistically similar with N_5P_3 (200 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}), N_5P_1 (200 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}), N_4P_3 (160 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) and minimum was with N_0P_0. At 90 DAT maximum LAI (7.81) was observed with N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) which was statistically at par with N_5P_3 (200 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}), N_2P_2

Table 3. Interaction effect of nitrogen and phosphorus on leaf area index of hybrid Heera1 at different days after transplanting

Treatment	Days after transplanting							
	15	30	45	60	75	90	105	At harvest
N_0P_0	0.03a	0.12ab	0.34b-d	0.81de	2.59d-f	4.87ef	3.85ef	1.79g
N_0P_1	0.02a	0.10b	0.32b-d	1.01b-e	2.51ef	5.00d-f	4.99b-f	1.99g
N_0P_2	0.02a	0.11b	0.28cd	0.89b-e	2.77c-f	4.70ef	3.70f	2.05g
N_0P_3	0.02a	0.11b	0.26d	0.78de	2.30f	4.40f	4.02d-f	2.44e-g
N_1P_0	0.02a	0.12ab	0.35b-d	0.69e	2.47ef	5.39c-f	4.81b-f	2.66e-g
N_1P_1	0.03a	0.11b	0.49ab	0.85b-e	2.49ef	5.28c-f	4.89b-f	2.15fg
N_1P_2	0.02a	0.11b	0.45a-d	1.04b-e	2.68d-f	5.18d-f	4.44c-f	2.62e-g
N_1P_3	0.03a	0.11b	0.43a-d	0.77de	2.75c-f	5.44c-f	5.29b-f	2.87e-g
N_2P_0	0.03a	0.15ab	0.46a-c	1.05b-e	3.79ab	7.02a-c	6.18a-c	4.01a-d
N_2P_1	0.02a	0.14ab	0.38a-d	1.23ab	3.39a-e	7.76a	7.49a	4.08a-c
N_2P_2	0.03a	0.15ab	0.34b-d	1.09b-d	4.04a	7.81a	7.64a	4.64a
N_2P_3	0.03a	0.14ab	0.39a-d	1.11b-d	3.32a-e	6.34a-e	7.72a	4.55ab
N_3P_0	0.02a	0.12ab	0.47a-c	1.04d-e	3.03b-f	6.45a-e	4.74b-f	2.73e-g
N_3P_1	0.03a	0.13ab	0.43a-d	0.80de	2.79c-f	5.59b-f	4.92b-f	2.13fg
N_3P_2	0.02a	0.12ab	0.49ab	0.97b-e	3.14a-f	4.91ef	4.78b-f	1.93g
N_3P_3	0.03a	0.12ab	0.50ab	0.96b-e	2.93b-f	6.37a-e	4.56b-f	2.34fg
N_4P_0	0.02a	0.12ab	0.50ab	1.11b-d	2.73c-f	5.83b-f	6.51ab	2.61e-g
N_4P_1	0.03a	0.11b	0.47ab	0.90b-e	3.16a-f	5.65b-f	5.79a-e	2.96d-g
N_4P_2	0.02a	0.12ab	0.39a-d	0.91b-e	2.65d-f	5.89b-f	3.92ef	1.83g
N_4P_3	0.02a	0.10b	0.55a	0.91b-e	3.44a-e	6.67a-d	5.46b-f	2.25fg
N_5P_0	0.03a	0.14ab	0.45a-c	1.21a-c	3.33a-e	6.98a-c	6.15a-c	2.59e-g
N_5P_1	0.03a	0.12ab	0.40a-d	0.83c-e	3.68a-c	6.33a-e	4.31c-f	2.82e-g
N_5P_2	0.03a	0.12ab	0.39a-d	1.15a-d	3.05 b-f	5.96b-f	6.04a-d	3.53b-e
N_5P_3	0.03a	0.18a	0.57a	1.50a	3.52 a-d	7.23ab	5.08b-f	3.30c-f
SE	**NS**	**0.02**	**0.05**	**0.11**	**0.28**	**0.51**	**0.60**	**0.34**
CV (%)	**17.81**	**20.36**	**22.40**	**20.03**	**16.10**	**14.79**	**19.66**	**21.37**

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}, P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

(USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}), N_4P_3 (160 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) and minimum was with N_0P_0. Similar trend was observed at 105 DAT and at harvesting time.

4.1.4 Total dry matter production

4.1.4.1 Effect of nitrogen

Dry matter is the material which was dried to a constant weight. Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first perquisite for high yield. TDM of roots, leaves, leaf sheath + stem and or panicles of plants data were measured at 30, 60, 90 and at harvest. It was evident from Figure 7 and Appendix VII that significant variation was found in the total dry matter accumulation at different growth stages. Accumulation of dry matter was very slow at early stage (30 DAT to 60 DAT) and increased progressively over time attaining the highest at harvesting time. The rate of increase, however, varied depending on the growth stages. At 30 DAT, higher total dry matter (0.20 g) was found with N_5 (200 kg N ha^{-1}) which was statistically similar with N_2 (USG @ 75 kg N ha^{-1}) (0.17 g), N_3 (120 kg N ha^{-1}) (0.16 g) and N_4 (160 kg N ha^{-1}) (0.16 g) and lowest (0.14 g) with N_1 (80 kg N ha^{-1}) which was at par with N_0. At 60 DAT, maximum total dry matter (4.90 g) was obtained with N_2 (USG @ 75 kg N ha^{-1}) which was statistically identical with N_5 (200 kg N ha^{-1}) (4.27 g) and minimum (2.41 g) with control (no nitrogen). The trend was also found at 90 DAT and at harvest. At 90 DAT, the highest total dry matter (38.78 g) was obtained with N_2 (USG

@ 75 kg N ha^{-1}) and lowest (18.26) with control treatment. The second highest (32.49 g) was identified with N_5 (200 kg N ha^{-1}) which was followed by N_4 (160 kg N ha^{-1}) (31.46 g) and N_3 (120 kg N ha^{-1}) (29.05 g). At harvesting time, higher total dry matter (66.26 g) was found with N_2 (USG @ 75 kg N ha^{-1}) and lowest (40.81g) with control which was 62.36% lower than N_2. The second highest total dry matter (54.34 g) was found with N_5 (200 kg N ha^{-1}) which was at par with N_4 (160 kg N ha^{-1}) (49.76 g) and N_3 (120 kg N ha^{-1}) (46.34 g). Masum *et al.* (2008) reveled that USG applied plants gave higher TDM compared to prilled urea. Geethadevi *et al*. (2000) concluded that application of 150 kg N ha^{-1} gave highest total dry matter per plant. Rambabu *et al*. (1983) and Rao *et al.* (1986) from their study concluded that USG was the most effective in increasing TDM than split application of urea.

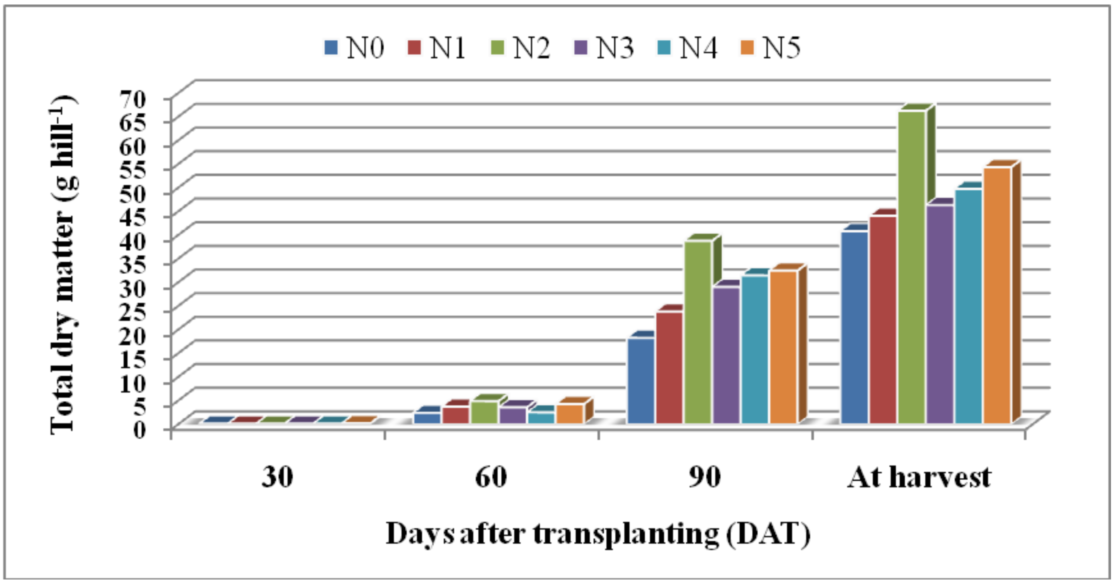

Figure 7. Effect of nitrogen on total dry matter (g hill^{-1}) of hybrid Heera1 at different days (SE = 0.02, 0.41, 1.85, 3.12 at 30, 60, 90 and harvest, respectively)

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}

4.1.4.2 Effect of phosphorus

The level of phosphorus has no significant difference to accumulate the total dry matter in hybrid rice. (Figure 8 and Appendix VII) Accumulation of total dry matter increased progressively over the time attaining the maximum at harvest. The rate of increase, however, varied depending on the growth stages. At 30 DAT, numerically higher total dry matter (0.17 g) was found with P_1 (30 kg P_2O_5 ha^{-1}) and lowest (0.15 g) with P_2 (50 kg P_2O_5 ha^{-1}). At 60 DAT, numerically maximum total dry matter (3.85 g) was obtained with P_2 (50 kg P_2O_5 ha^{-1}) and lowest with control. At 90 DAT, numerically highest total dry matter (30.29 g) was identified with P_3 (70 kg P_2O_5 ha^{-1}) and lowest with P_0. But application of 50 kg P_2O_5 ha^{-1} (P_2) produced numerically maximum total dry matter (52.90 g) at harvest while minimum (46.71 g) with P_0 which was 13.25% lower than P_2. Positive influence of phosphorus on total dry matter in rice was also reported by Gupta and Bhadra (1980) and Sharkar and Chowdhury (1988).

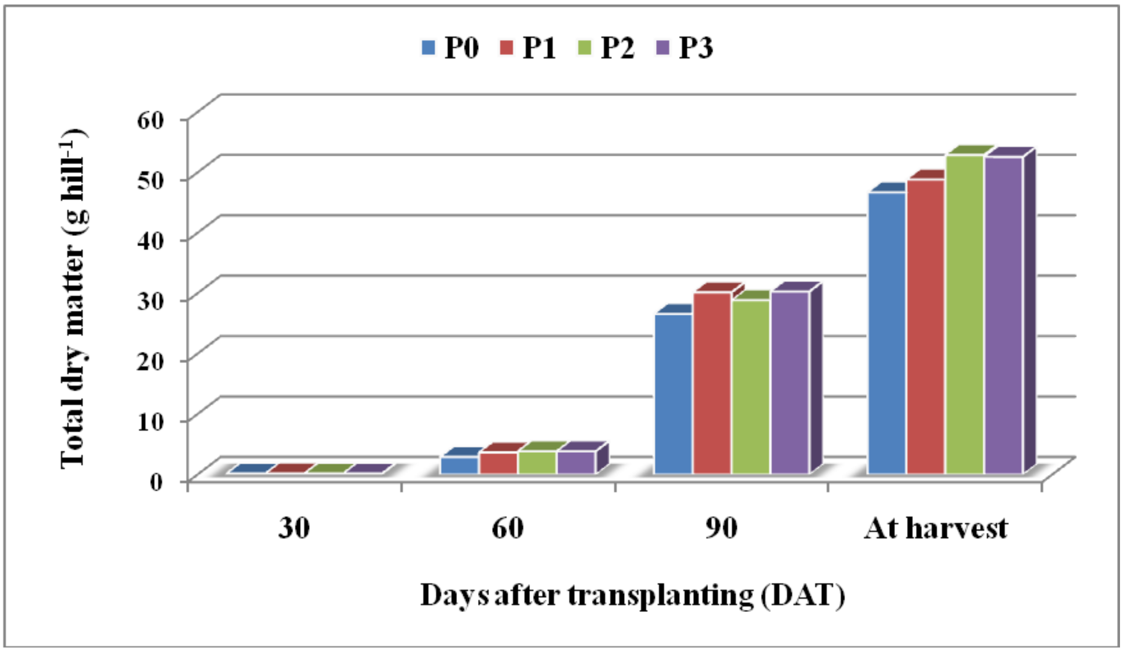

Figure 8. Effect of phosphorus on total dry matter of hybrid Heera1at different days (SE = 0.01, 0.34, 1.51, 2.55 at 30, 60, 90 and harvest, respectively)

P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.1.4.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus has significant difference to accumulate the total dry matter in hybrid rice (Table 4 and appendix VII). Accumulation of total dry matter increased progressively over the time attaining the maximum at harvest. The rate of increase, however, varied depending on the growth stages. At 30 DAT, maximum total dry weight (0.24 g) was obtained with the treatment combination of N_5P_2 (200 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) which was similar with N_3P_1 (120 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (0.21 g), N_5P_3 (200 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (0.21 g), N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (0.20 g), N_4P_3 (160 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1})

(0.17 g) and minimum (0.08 g) with N_0P_2. At 60 DAT, highest total dry matter (5.57 g) was observed with N_2P_0 (USG @ 75 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1}) and followed by N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (5.08 g), N_5P_3 (200 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (4.87 g), N_5P_2 (200 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) and lowest (1.48 g) with N_0P_0. At 90 DAT, the highest total dry matter (46.05 g) was found with N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) and at par with N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (38.11 g), N_5P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (37.13 g), N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (36.42 g) and N_5P_2 (200 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (35.77 g) and lowest (16.07 g) with N_0P_0 which was 186.56% lower than N_2P_3. The treatment combination of N_2P_3 (USG @ 75 kg N ha^{-1} and 75 kg P_2O_5 ha^{-1}) produced highest total dry matter (75 g) at harvest and similar with N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (67.85 g) and produced 97.77% higher than control combination of treatment. Saito *et al.* (2005) reported that application of 90 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}gave higher total dry matter.

Table 4. Interaction effect of nitrogen and phosphorus on total dry matter (g hill^{-1}) of hybrid Heera1 at different days after transplanting

Treatment	Days after transplanting			
	30	60	90	At harvest
N_0P_0	0.18a-c	1.49f	16.07g	39.51de
N_0P_1	0.19a-c	3.27a-f	19.14e-g	44.36c-e
N_0P_2	0.08c	2.88a-f	16.96fg	41.90c-e
N_0P_3	0.14a-c	1.99ef	20.87d-g	37.49e
N_1P_0	0.14a-c	2.02d-f	24.20c-g	39.44de
N_1P_1	0.12bc	3.49a-f	28.79b-f	52.95b-e
N_1P_2	0.14a-c	5.18ab	21.27d-g	39.25de
N_1P_3	0.14a-c	4.27a-f	21.04d-g	44.57c-e
N_2P_0	0.16a-c	5.57a	34.54a-c	62.51a-c
N_2P_1	0.20ab	5.09a-c	36.42a-c	56.68b-e
N_2P_2	0.17a-c	4.70a-e	38.11ab	67.85ab
N_2P_3	0.13bc	4.26a-f	46.05a	75.00a
N_3P_0	0.16a-c	3.36a-f	23.99c-g	44.76c-e
N_3P_1	0.22ab	3.87a-f	28.45b-g	45.41c-e
N_3P_2	0.12bc	3.19a-f	31.49b-e	48.47b-e
N_3P_3	0.13bc	3.93a-f	32.26b-d	46.73b-e
N_4P_0	0.17a-c	1.45f	32.28b-d	46.00c-e
N_4P_1	0.13bc	2.56b-f	31.08b-e	43.90c-e
N_4P_2	0.15a-c	2.31c-f	29.59b-e	60.54a-d
N_4P_3	0.17a-c	3.79a-f	32.87b-d	48.60b-e
N_5P_0	0.18a-c	3.62a-f	28.44b-g	48.05b-e
N_5P_1	0.17a-c	3.70a-f	37.13ab	49.75b-e
N_5P_2	0.24a	4.86a-d	35.77a-c	59.39a-d
N_5P_3	0.21ab	4.87a-d	28.62b-f	60.16a-d
SE	**0.03**	**0.83**	**3.71**	**6.24**
CV (%)	**25.56**	**30.19**	**22.16**	**21.51**

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}, P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.2 Yield contributing characters

4.2.1Effective tiller hill^{-1}

4.2.1.1Effect of nitrogen

The number of effective tillers hill^{-1} was significantly influenced by nitrogen application (Table 5 and appendix VIII). The highest number of effective tillers hill^{-1} (13.63) was obtained in N_2 (USG @ 75 kg N ha^{-1}) comprising of urea super granules whereas, the lowest (10.12) was obtained from N_0 (0 kg N ha^{-1}) and followed by N_1 (80 kg N ha^{-1}), N_4 (160 kg N ha^{-1}) and N_5 (200 kg N ha^{-1}). The second highest number of effective tiller (12.11) was found with N_3 (120 kg N ha^{-1}). Hasanuzzaman *et al*. (2009) obtained maximum effected tiller with USG @ 75 kg N ha^{-1}. BRRI (2009) reported that in *boro* season applied N @ 100 kg ha^{-1} as USG or PU produced maximum effective tillers. Masum *et al*. (2010) reported that placement of N in the form of USG @ 58 kg ha^{-1} produced the highest number of effective tiller in *aman* season. Adequacy of nitrogen and uniform supply through USG probably favoured the cellular activities during panicle formation and development which leaded to increase number of effective tillers hill^{-1}. Thakur (1991b) and Gosh *et al.* (1991) also agreed to this view.

4.2.1.2 Effect of phosphorus

Effective tillers hill^{-1} of hybrid rice was also varied significantly due to P fertilizer application (Table 5 and appendix VIII) Application of 30 kg P_2O_5 ha^{-1} produced the highest number of effective tillers hill^{-1} (12.41) which was statistically at par with 50 kg P_2O_5 ha^{-1} (11.77) and 70 kg P_2O_5 ha^{-1} (11.35).

Plant grown without P fertilizer had the lowest effective tillers $hill^{-1}$ (10.56). Application of 30 kg P_2O_5 ha^{-1}, 50 kg P_2O_5 ha^{-1} and 70 kg P_2O_5 ha^{-1} also produced 17.52%, 11.45% and 7.48% higher effective tillers over the control treatment. Alam *et al*. (2009a) reported that 75 kg P_2O_5 ha^{-1} produced higher effective tillers $hill^{-1}$. A similar result was reported by Katyal (1978). Matsua *et al*. (1995) also reported that it is necessary to apply much P fertilizers to help rice plants to accelerate the P absorption for increased tillering.

4.2.1.3 Interaction effect of nitrogen and phosphorus

The effect of interaction between N and P was found to be significant in respect of number of effective tillers $hill^{-1}$ (Table 5 and appendix VIII). Combination of N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) produced the highest number of productive tillers $hill^{-1}$ (15.25) which was statistically similar to N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (14.03), N_3P_3 (120 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (13.13), N_4P_2 (160 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (12.87), N_3P_1 (120 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (12.73), N_2P_3 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (12.67), N_4P_2 (160 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (12.64). However, the lowest number of effective tillers $hill^{-1}$ was observed from N_0P_0, N_0P_1 and N_0P_3. Venkateswarlu and Singh (1980) observed highest number of effective tillers with 120 kg N + 60 kg P_2O_5 + 45 kg K_2O ha^{-1} followed by 80 kg N + 40 kg P_2O_5 + 30 kg K_2O ha^{-1}.

4.2.2 Panicle length

4.2.2.1 Effect of nitrogen

Panicle length was influenced significantly by nitrogen application (Table 5 and appendix VIII). The highest panicle length (24.29 cm) was observed in N_2 (USG @ 75 kg N ha^{-1}) which was statistically at par with N_4 (160 kg N ha^{-1}) (23.57 cm). Application of USG @ 75 kg N ha^{-1} produced 4.92% higher panicle length over the control treatment. The untreated control plants (0 kg N ha^{-1}) produced the shortest panicle (22.30 cm) which was statistically similar with N_1 (22.95 cm), N_5 (23.04 cm), N_3 (23.11cm). The result was corroborated with the findings of Hasanuzzaman *et al*. (2009) who found that USG @ 75 kg N ha^{-1} produced the longest panicle.

4.2.2.2 Effect of phosphorus

Phosphorus had significant role in increasing the panicle length (Table 5 and appendix VIII). The longest panicle length (23.98 cm) was found in P_1 (30 kg P_2O_5 ha^{-1}) treatment which was statistically similar with P_2 (50 kg P_2O_5 ha^{-1}) (23.98 cm) and P_3 (70 kg P_2O_5 ha^{-1}) (23.72 cm). The shortest panicle length (21.36 cm) was found in P_0 treatment. Control treatment produced 12.27% lower panicle length over 30 kg P_2O_5 ha^{-1}. Similar result was reported for low land rice by Sahar and Burbey (2003).

4.2.2.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus levels on hybrid rice had significant effect on panicle length (Table 5 and appendix VIII). The treatment N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) produced the longest panicle

(25.09 cm) and at par with N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (24.63 cm), N_4P_3 (160 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (24.61 cm), N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (24.48 cm), and N_3P_1 (120 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (24.19 cm). The shortest panicle was observed from the interaction treatment of N_0P_0 (20.85 cm) and N_1P_0 (20.29 cm). N_2P_3 produced 23.66% higher panicle length than control.. Asif *et al.* (2000) reported that NPK levels significantly increase the panicle length when NPK fertilizer applied in 180-90-90 kg ha^{-1}

4.2.3 Filled grains panicle^{-1}

4.2.3.1 Effect of nitrogen

The application of nitrogen significantly increased the number of filled grains panicle^{-1} (Table 5 and appendix VIII). The highest filled grains panicle^{-1} (154.7) was found from N_2 (USG @ 75 kg N ha^{-1}) and at par with 160 kg N ha^{-1} (145.8), 120 kg N ha^{-1} (145.4) and 200 kg N ha^{-1} (144.1) whereas, the lowest (126.2) was obtained from N_0 (0 kg N ha^{-1}). Application of N_2 (USG @ 75 kg N ha^{-1}) produced 22.58% higher filled grain panicle^{-1} than control. Rama *et al.* (1989) found higher filled grains panicle^{-1} with 40, 80 or 120 kg N ha^{-1} applied as USG. The present results supported those results. Decreased number of filled grain panicle^{-1} with the higher level of nitrogen might be due to higher accumulation of N in vegetative parts with lower partitioning of dry matter to the grains. The result also agreed with the findings of Kumar *et al*. (1995).

4.2.3.2 Effect of phosphorus

Filled grains panicle^{-1} was not significantly affected by different level of phosphorus (Table 5 and appendix VIII). Numerically the highest number of filled grains panicle^{-1} (146.62) was observed with P_3 (70 kg P_2O_5 ha^{-1}). Control treatment i.e P_0 and P_1 (30 kg P_2O_5 ha^{-1}) produced lowest number of filled grain panicle^{-1}. Sahar and Burbey (2003) showed that increasing the rate of P significantly affected the grain number panicle^{-1}.

4.2.3.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus was found significant on filled grains panicle^{-1} (Table 5 and appendix VIII). Highest filled grains panicle^{-1} (160.03) was found from the combination of N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) which was similar with N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}), N_3P_2 (120 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}), N_4P_3 (160 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}). The lowest (122.33 and 115.30) was found in N_0P_0 and N_1P_0. N_2P_3 produced 30.83% higher filled grains per panicle than control. Singh *et al.* (2003) reported 120 kg N ha^{-1} and 26 kg P_2O_5 ha^{-1} produced highest number of filled grains per panicle.

4.2.4 Unfilled grains panicle^{-1}

4.2.4.1 Effect of nitrogen

Nitrogen had significant influence on the unfilled grains panicle^{-1} (Table 5 and appendix VIII). The highest number of unfilled grains panicle^{-1} (4.71) was found in control treatment (0 kg N ha^{-1}). Application of 80 kg N ha^{-1}, 200 kg N

ha^{-1} and USG @ 75 kg N ha^{-1} can reduce the unfilled grain up to 36.92%, 26.54% and 25.05%, respectively. Minimum (3.44) unfilled grains $panicle^{-1}$ was obtained from the N_1 (80 kg N ha^{-1}) treatment and identical with 200 kg N ha^{-1} and USG @ 75 kg N ha^{-1}.The result was supported by BRRI (2006) that 0 kg ha^{-1} N produced the higher number of unfilled grains $panicle^{-1}$ compared to 90 and 120 kg N ha^{-1}.

4.2.4.2Effect of phosphorus

Unfilled grains $panicle^{-1}$ was significantly affected by different phosphorus levels (Table 5 and appendix VIII). Treatment P_2 (50 kg P_2O_5 ha^{-1}) produced the lowest unfilled grains $panicle^{-1}$ (3.29). Due to lack of phosphorus the highest number of unfilled grains $panicle^{-1}$ (4.77) was found in control treatment (P_0) which was 44.98% higher over 50 kg P_2O_5 ha^{-1}.The findings are in agreement with those of Fageria and Barosa- Filho (1982).

4.2.4.3 Interaction effect of nitrogen and phosphorus

It was observed in the table 5 and appendix VIII that the interaction of nitrogen and phosphorus significantly affected the number of unfilled grain $panicle^{-1}$. The maximum unfilled grains $panicle^{-1}$ (7.03) was found in combination of $N_0P_{0.}$ The minimum number of unfilled grains (2.75) was found in N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) which was 155.63% lower than control treatment. The second highest unfilled grain was found with N_4P_0 (160 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1}).

4.2.5 Total grains panicle^{-1}

4.2.5.1 Effect of nitrogen

Total grains panicle^{-1} was significantly influenced by nitrogen application (Table 5 and appendix VIII). The highest number of total grains panicle^{-1} (159.20) was found from N_2 (USG@ 75 kg N ha^{-1}) which was followed by 160 kg N ha^{-1} (149.9), 120 kg N ha^{-1} (149.5) and 200 kg N ha^{-1} (147.5). The lowest total grains panicle^{-1} (130.9) was obtained from N_0 (0 kg N ha^{-1}) treatment which was statistically at par with 80 kg N ha^{-1}. N_2 (USG@ 75 kg N ha^{-1}) produced 20.86% higher total grains panicle^{-1} than control. BRRI (2006) reported that grains panicle^{-1} increased with higher N rates up to 120 kg N ha^{-1}. Awan *et al.* (2011) reported that maximum number of grains panicle^{-1}was produced in case of 156 kg N ha^{-1}. Gorgy *et al.* (2009) found maximum number of grains panicle^{-1} with three equal split of 165 kg N ha^{-1}.

4.2.5.2 Effect of phosphorus

Total grains panicle^{-1} was not significantly affected by different level of phosphorus (Table 5 and appendix VIII). Numerically the highest total grains panicle^{-1} (150.35) was reported at P_3 (70 kg P_2O_5 ha^{-1}) and P_1 (30 kg P_2O_5 ha^{-1}) produced lowest filled grain panicle^{-1}. Rafique *et al.* (2005) reported that 50 kg P_2O_5 ha^{-1} gave the highest total grains panicle^{-1}.

4.2.5.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus was found significant on total grains panicle^{-1} (Table 5 and appendix VIII). The highest total grains panicle^{-1} (163.17) was found with N_2P_1(USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) and similar with N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (162.8), N_3P_2 (120 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (157.2), N_3P_3 (120 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (156.5), N_4P_3 (160 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (155.5), N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}). The lowest number of total grains $panicle^{-1}$ (118.87) was observed in N_0P_1 which was at par with N_0P_0.

4.2.6 1000 grain weight

4.2.6.1 Effect of nitrogen

The weight of 1000 grains was significantly influenced by the different levels of nitrogen (Table 5 and appendix VIII). The highest thousand grain weight (29.35 g) was recorded in N_2 (USG @75 kg N ha^{-1}) treatment and lowest (27.86 g) in N_0 (0 kg N ha^{-1}) and identical with 80 kg N ha^{-1} (28.14). The second height thousand grain weight (28.43) was found with N_5 (200 kg N ha^{-1}) and similar with 120 kg N ha^{-1} (28.10), 160 kg N ha^{-1} (28.12). Hasanuzzaman *et al*. (2009) reported that application of USG @ 75 kg N ha^{-1} gave the highest thousand grain weight. Gorgy *et al*. (2009) reported that application of 165 kg N ha^{-1} with three equal splits gave maximum value of thousand grain weight. Awan *et al*. found application of 156 kg N ha^{-1} gave maximum 1000 grain. But the result did not agree with the findings of Ibrahiem *et al*. (2004) that with the increasing levels of nitrogen had no significant effect on 1000 grain weight. Islam *et al*. (2008) reported weight of 1000 grain weight was not significantly influenced by N level as it is mostly governed by genetic makeup of the variety.

4.2.6.2 Effect of phosphorus

Thousand grain weight of hybrid rice also varied significantly due to phosphorus application (Table 5 and appendix VIII). The highest (28.64 g) was recorded for P_3 (70 kg P_2O_5 ha^{-1}) which was significantly at par with P_2 (50 kg P_2O_5 ha^{-1}) (28.47g). The lowest thousand grain weight (28.06 g) was obtained in P_0 (0 kg P_2O_5 ha^{-1}). Application of 70 kg P_2O_5 ha^{-1} produced 2.07% higher thousand grain weight than control. Shah (2002) reported application of 30 kg ha^{-1} P gave highest 1000 grain weight. Alam *et al*. (2009d) found that application of 72 kg P_2O_5 ha^{-1} gave the highest 1000 grain weight.

4.2.6.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus had significant effect on 1000 grain weight (Table 5 and appendix VIII). The highest 1000 grain weight (29.65 g) was observed with N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) which was followed by N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (29.33 g), N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) (29.21 g). However, the lowest seed weight (27.53 g) was observed in combination with $N_0P_{0.}$ Application of N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) gave 7.70% higher thousand grains weight over the control treatment. Saito *et al.* (2005) conducted an experiment and reported that application of 90 kg N ha^{-1} with 50 kg P_2O_5 ha^{-1} produced highest thousand grains weight.

Table 5. Effect of nitrogen and phosphorus and their interaction on yield contributing characters of hybrid Heera1

Treatment	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	1000 grain weight (g)
Nitrogen						
N_0	10.12c	22.30c	126.16c	4.71a	130.87c	27.86c
N_1	10.26c	22.96bc	137.71bc	3.44b	141.15bc	28.14bc
N_2	13.63a	24.29a	154.67a	3.53b	159.20a	29.35a
N_3	12.11b	23.11bc	145.38ab	4.13ab	149.52ab	28.11bc
N_4	11.59bc	23.57ab	145.78ab	4.13ab	149.92ab	28.12bc
N_5	11.42bc	23.04bc	144.08ab	3.45b	147.54ab	28.43b
SE	**0.51**	**0.29**	**4.15**	**0.28**	**3.44**	**0.14**
CV (%)	**15.98**	**3.90**	**14.91**	**30.28**	**14.94**	**2.34**
Phosphorus						
P_0	10.56b	21.36b	140.83a	4.77a	145.60a	28.06c
P_1	12.41a	23.98a	137.37a	3.81b	141.18a	28.16bc
P_2	11.77ab	23.79a	144.37a	3.29b	147.66a	28.47ab
P_3	11.35ab	23.72a	146.62a	3.73b	150.35a	28.64a
SE	**0.41**	**0.23**	**NS**	**0.23**	**NS**	**0.12**
CV (%)	**15.24**	**4.26**	**10.11**	**25.29**	**9.97**	**1.74**
Interaction of nitrogen and phosphorus						
N_0P_0	9.73c-e	20.85f	122.33de	7.03a	129.37bc	27.53f
N_0P_1	10.70b-e	23.17a-e	115.30e	3.57b-d	118.87c	27.74ef
N_0P_2	10.50c-e	23.08b-e	127.73b-e	3.10d	130.83bc	28.43b-f
N_0P_3	9.53de	22.08c-f	139.27a-e	5.13bc	144.40a-c	27.72ef
N_1P_0	8.80e	20.29f	137.50a-e	4.00b-d	141.50a-c	27.74ef
N_1P_1	10.90b-e	23.98a-c	126.77c-e	3.43b-d	130.20bc	27.95ef
N_1P_2	11.00b-e	23.45a-d	145.77a-d	3.50b-d	149.27ab	28.26c-f
N_1P_3	10.35c-e	24.09ab	140.80a-e	2.83d	143.63a-c	28.62b-e
N_2P_0	12.57a-d	22.97b-e	149.87a-d	4.10b-d	153.97ab	29.22a-c
N_2P_1	15.25a	24.63ab	159.10a	4.07b-d	163.17a	29.33ab
N_2P_2	14.03ab	24.48ab	149.67a-d	3.20cd	152.87ab	29.21a-c
N_2P_3	12.69a-d	25.09a	160.03a	2.75d	162.79a	29.65a
N_3P_0	11.73b-e	20.98f	139.87a-e	4.47b-d	144.33a-c	27.53f
N_3P_1	12.73a-d	24.19ab	136.10a-e	3.93b-d	140.03a-c	27.94ef
N_3P_2	10.83b-e	23.82a-c	153.70a-c	3.47b-d	157.17ab	28.38b-f
N_3P_3	13.13a-c	23.46a-d	151.87a-c	4.67b-d	156.53ab	28.57b-e
N_4P_0	9.97c-e	21.76d-f	138.90a-e	5.37b	144.27a-c	27.91ef
N_4P_1	12.64a-d	23.94a-c	143.53a-e	4.33b-d	147.87ab	27.84ef
N_4P_2	12.87a-d	23.98a-c	148.80a-d	3.27cd	152.07ab	28.43b-f
N_4P_3	10.90b-e	24.61ab	151.90a-c	3.57b-d	155.47ab	28.29c-f
N_5P_0	10.55b-e	21.31ef	156.50ab	3.67b-d	160.17a	28.45b-f
N_5P_1	12.24a-e	23.95a-c	143.40a-e	3.53b-d	146.93a-c	28.16d-f
N_5P_2	11.40b-e	23.89a-c	140.57a-e	3.20cd	143.77a-c	28.10d-f
N_5P_3	11.50b-e	23.01b-e	135.87a-e	3.43b-d	139.30a-c	29.01a-d
SE	**1.01**	**0.57**	**8.307**	**0.57**	**8.42**	**0.29**
CV (%)	**15.24**	**4.26**	**10.11**	**25.29**	**9.97**	**1.74**

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}, P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.3 Yields

4.3.1 Grain yield

4.3.1.1 Effect of nitrogen

Grain yield was significantly influenced by different levels of nitrogen (Figure 9 and appendix IX). Application of USG @ 75 kg N ha^{-1} produced the highest grain yield (9.42 t ha^{-1}) followed by 160 kg N ha^{-1} (8.58 t ha^{-1}). Plants grown without N had the lowest yield (5.33 t ha^{-1}) which was statistically at par with N_1 (80 kg N ha^{-1}) (5.96 kg N ha^{-1}). The second highest grain yield (7.00 t ha^{-1}) was found with N_5 (200 kg N ha^{-1}). The increase in yield by the use of USG @ 75 kg N ha^{-1} and 160 kg N ha^{-1} was 76.74% and 60.98%, respectively over the control treatment. Placement of nitrogen fertilizer in the form of USG @ 75 kg N ha^{-1} in the present experiment produced the highest number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ which ultimately gave higher grain yield. BRRI (2009) reported that highest grain yield was recorded when N applied as USG @ 100 kg N ha^{-1}. BRRI (2006) reported that cultivation of hybrid rice in *boro* required 120 kg N ha^{-1}. BRRI (2000) noted that USG gave 18% yield increase over the recommended prilled urea. In the present experiment 9.79% higher grain yield was found in USG over urea. Similar results were reported by Hasanuzzaman *et al.* (2009), Masum *et al.* (2008), Mishra *et al.* (2000) and Raju *et al.* (1987) who observed urea supergranules produced the highest grain yield and proved significantly superior to other sources.

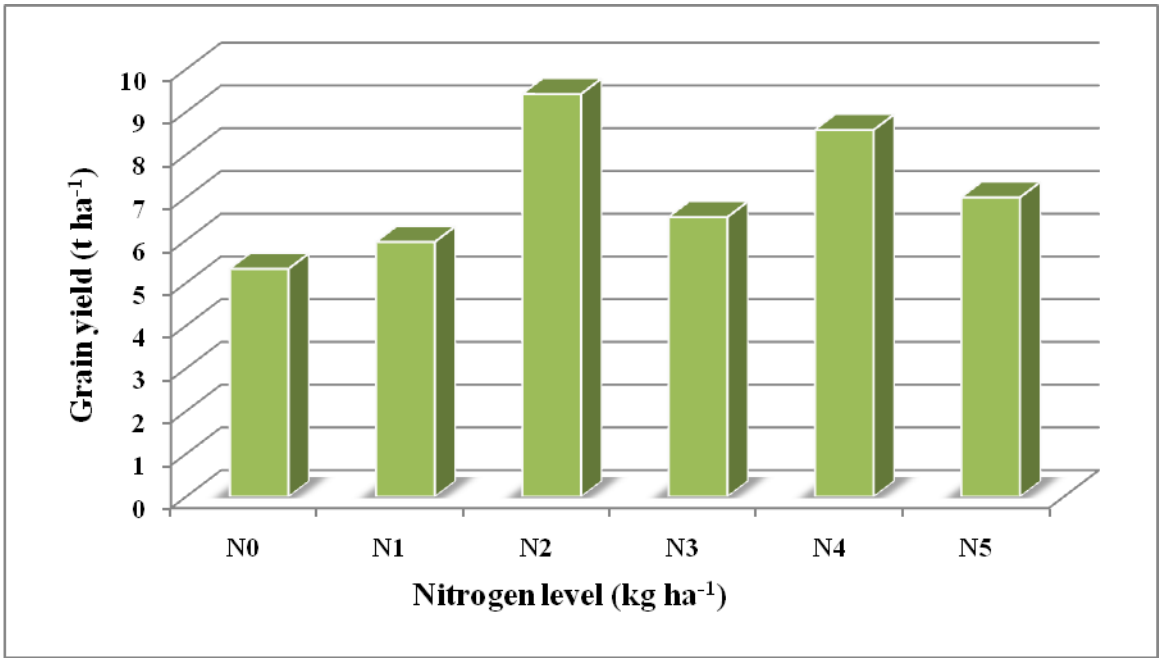

Figure 9.Effect of nitrogen on grain yield of hybrid Heera1 (SE = 0.46)

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}

4.3.1.2 Effect of phosphorus

The impact of P on grain yield ha^{-1} was not significantly affected by different level of phosphorus (Figure 10 and appendix IX). Numerically the highest number of grain yield (7.58 t ha^{-1}) was observed with P_2 (50 kg P_2O_5 ha^{-1}) and P_0 (0 kg P_2O_5 ha^{-1}) produced the lowest grain yield ha^{-1}. Shah (2002) reported similar response of P on grain yield. Brohi *et al*. (1998) showed application of 50 kg P_2O_5 ha^{-1} is sufficient for rice cultivation. BRRI (2009) reported that 10 kg P_2O_5 ha^{-1} significantly increase grain yield and at par with 20 kg P_2O_5 ha^{-1} and kg P_2O_5 ha^{-1}.

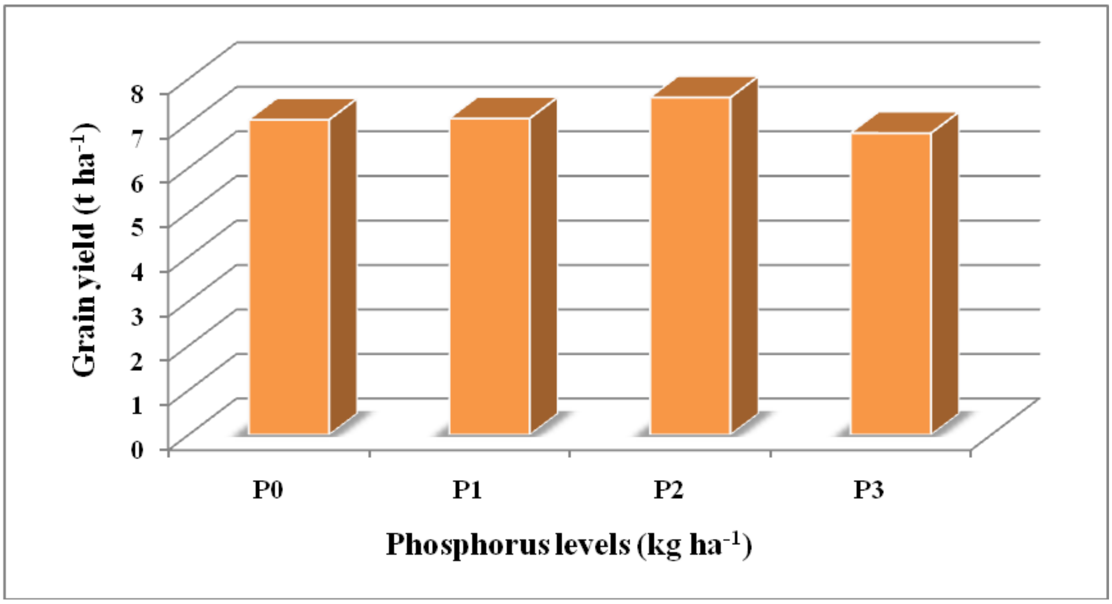

Figure 10. Effect of phosphorus on grain yield of hybrid rice (SE = 0.38)

P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.3.1.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus exerted significant influence on the grain yield (Table 6 and appendix IX). Combination of N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) produced the highest grain yield (9.83 t ha^{-1}) which was followed by N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (9.50 t ha^{-1}), N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) (9.17 t ha^{-1}). The lowest (4.83 t ha^{-1}) was found with N_0P_2 followed by N_0P_0 (5.17 t ha^{-1}). Application of N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) produced 90.13% higher grain yield over control treatment.

4.3.2 Straw yield

4.3.2.1 Effect of nitrogen

From Figure 11 and appendix IX, it was revealed that straw yield was significantly affected due to the application of nitrogen. The highest straw yield was of 13.33 t ha^{-1} was obtained from N_2 (USG @ 75 kg N ha^{-1}) and followed by N_5 (200 kg N ha^{-1}) (11.67 t ha^{-1}). The lowest straw yield (6.42 t ha^{-1}) was observed in N_0 (0 kg N ha^{-1}) and similar with 80 kg N ha^{-1} (7.67 t ha^{-1}). Application of N_2 (USG @ 75 kg N ha^{-1}) produced 107.63% and 73.79% higher straw yield than control and 80 kg N ha^{-1} , respectively. BRRI (2009) reported application of 150 kg N ha^{-1} gave the highest yield. Hasanuzzaman *et al*. (2009) reported application of 200 kg N ha^{-1} and USG @ 75 kg N ha^{-1} gave highest straw yield. Awan *et al*. (2011) observed application of 156 kg N ha^{-1} gave highest straw yield.

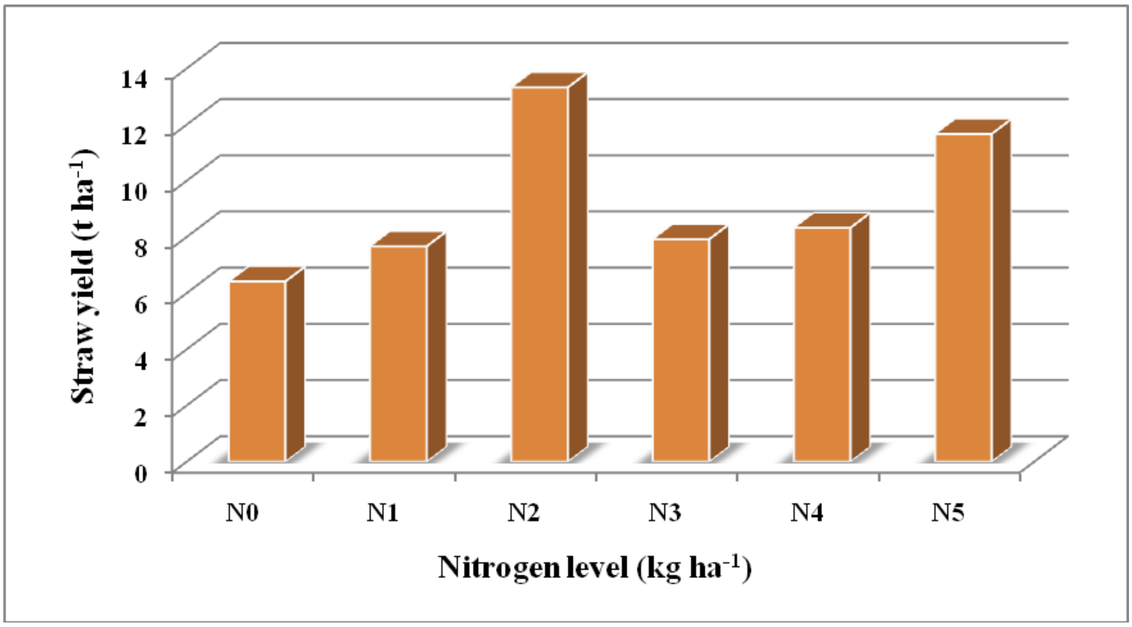

Figure 11.Effect of nitrogen on straw yield of hybrid Heera1 (SE = 0.73)

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}

4.3.2.2 Effect of phosphorus

The impact of P on straw yield was not significantly affected by different level of phosphorus (Figure 12 and appendix IX). Numerically the highest number of straw yield (9.61 t ha^{-1}) was recorded at P_1 (30 kg P_2O_5 ha^{-1}). Application of P_0 (0 kg P_2O_5 ha^{-1}) produced lowest straw yield (8.75 t ha^{-1}). P_1 (30 kg P_2O_5 ha^{-1}) produced 9.93% higher over the 30 kg P_2O_5 ha^{-1}. Alam *et al*. (2009d) also found that application of 48 kg P_2O_5 ha^{-1} and 72 kg P_2O_5 ha^{-1} gave higher straw yield.

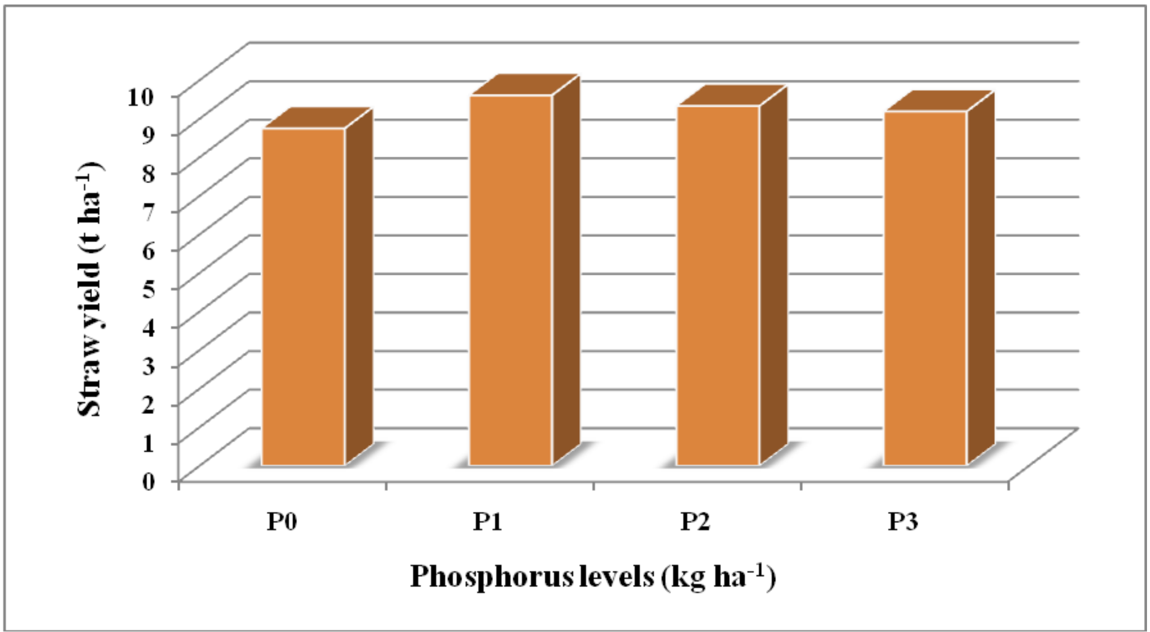

Figure 12. Effect of phosphorus on straw yield of hybrid Heera1 (SE = 0.59)

P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.3.2.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus was observed significant on straw yield (Table 6 and appendix IX). Highest (15.00 t ha^{-1}) straw yield was found from the combination of N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1})

followed by N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (13.17 t ha^{-1}). The lowest straw yield (5.50 t ha^{-1}) was found with the combination of N_0P_1 followed by N_0P_0 (5.67 t ha^{-1}). Application of N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) gave 164.55% higher straw yield than control treatment.

4.3.3 Biological yield

4.3.3.1 Effect of nitrogen

From Figure 13 and appendix IX it was observed that biological yield was significantly affected by the nitrogen. Maximum (22.75 t ha^{-1}) biological yield was measured from the N_2 (USG @) 75 kg N ha^{-1}) treated plots. Minimum (11.75 t ha^{-1}) from N_0 (0 kg N ha^{-1}) followed by 80 kg N ha^{-1} (13.63 t ha^{-1}), 120 kg N ha^{-1} (14.46 t ha^{-1}). N_2 (USG @) 75 kg N ha^{-1}) produced 93.62% higher biological yield than N_0. The second highest biological yield (18.67 t ha^{-1}) was observed with 200 kg N ha^{-1} and similar with 160 kg N ha^{-1} (16.92 t ha^{-1}). The result agreed with the findings of Ahmed *et al.* (2005) who observed the effect of nitrogen dose on biological yield (t ha^{-1}) of rice.

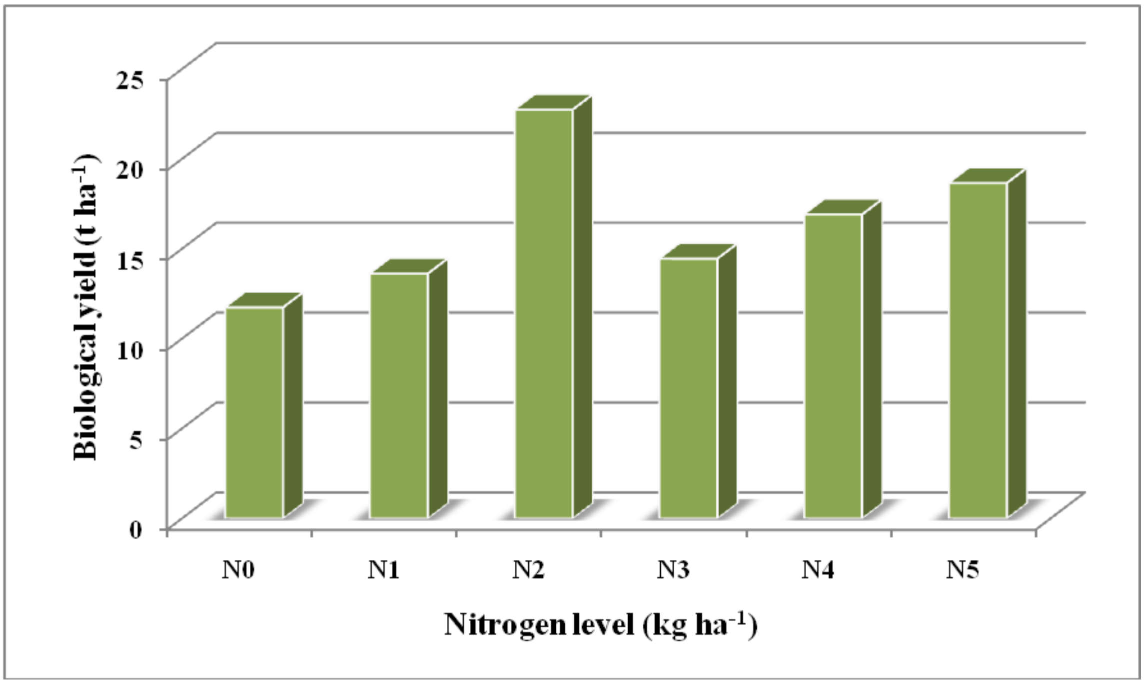

Figure 13. Effect of nitrogen on biological yield of hybrid Heera1 (SE = 0.94)

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}),

N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}

4.3.3.2 Effect of Phosphorus

Biological yield was not significantly affected by different levels of phosphorus (Figure 14 and appendix IX). Numerically the highest number of biological yield (16.92 t ha^{-1}) was reported at P_2 (50 kg P_2O_5 ha^{-1}) followed by P_1 (30 kg P_2O_5 ha^{-1}) (16.72 t ha^{-1}). Application of P_0 (0 kg P_2O_5 ha^{-1}) produced lowest straw yield (15.83 t ha^{-1}). P_2 (50 kg P_2O_5 ha^{-1}) produced 6.89% higher biological yield over control (0 kg P_2O_5 ha^{-1}).

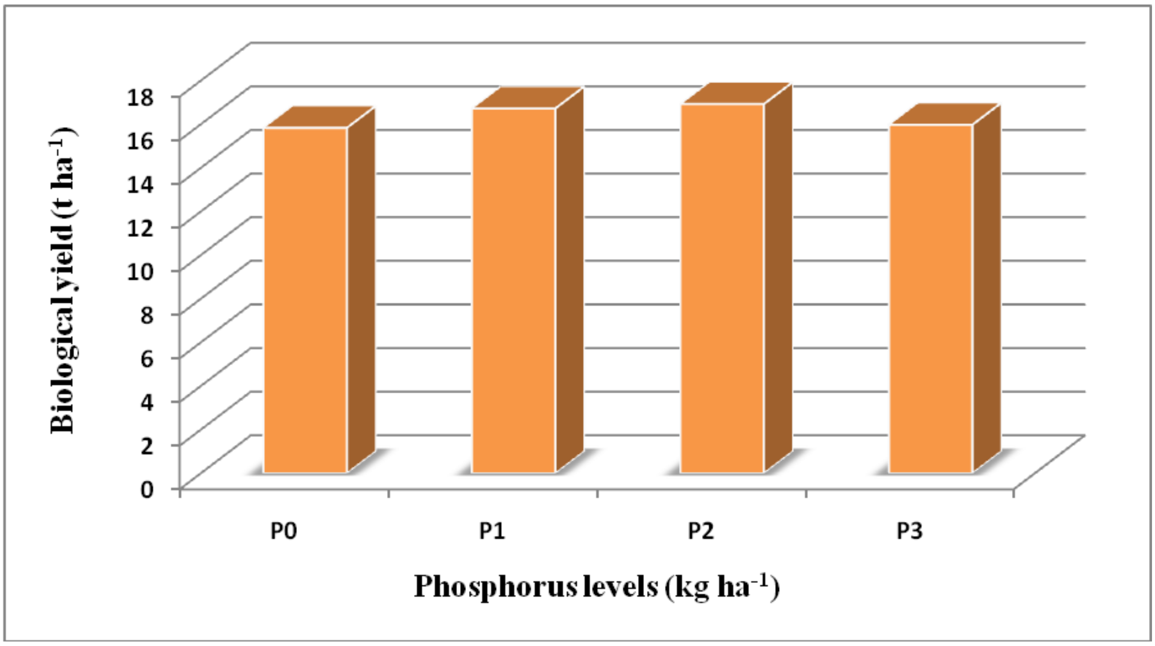

Figure 14. Effect of phosphorus on biological yield of hybrid Heera1 (SE = 0.77)

P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.3.3.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus was observed significant on biological yield (Table 6 and appendix IX). Highest biological yield (24.83 t ha^{-1}) was found from the combination of N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) followed by N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) (22.67 t ha^{-1}). The lowest biological yield (10.83 t ha^{-1}) was found from the combination of N_0P_0 which was statistically identical with N_0P_1, N_0P_3, and N_0P_2. Application of N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) produced 129.27% higher biological yield than control treatment.

4.4 Harvest index

4.4.1 Effect of nitrogen

Effect of nitrogen doses exerted significant variation on harvest index (Figure 15 and appendix IX). Harvest index was highest (51.75%) in N_4 (160 kg N ha^{-1}) followed by N_3 (120 kg N ha^{-1}) (46.00%) and the lowest harvest index (38.23%) in N_5 (200 kg N ha^{-1}). Awan *et al*. (2011) reported highest harvest index was found with 156 kg N ha^{-1}.

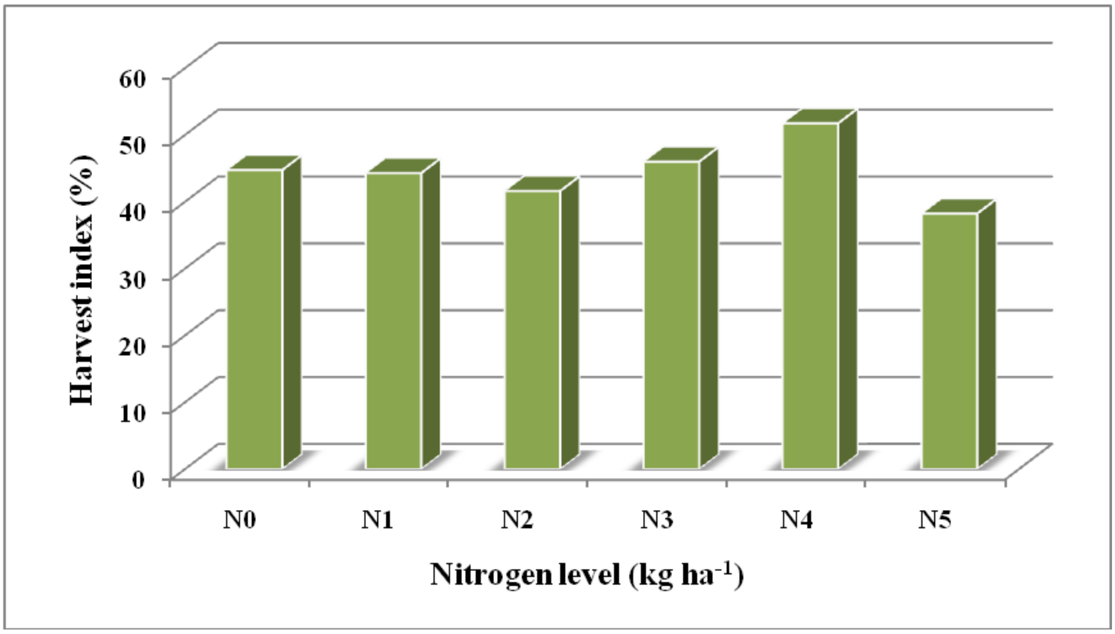

Figure 15.Effect of nitrogen on harvest index of hybrid Heera1 (SE = 2.21)

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}),

N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}

4.4.2 Effect of phosphorus

There was no significant effect of phosphorus was found on the harvest index (Figure 16 and appendix IX). Maximum harvest index (46.40%) was obtained from the treatment of P_2 (50 kg P_2O_5 ha^{-1}) and the lowest (42.18%) from P_3 (70 kg P_2O_5 ha^{-1}).

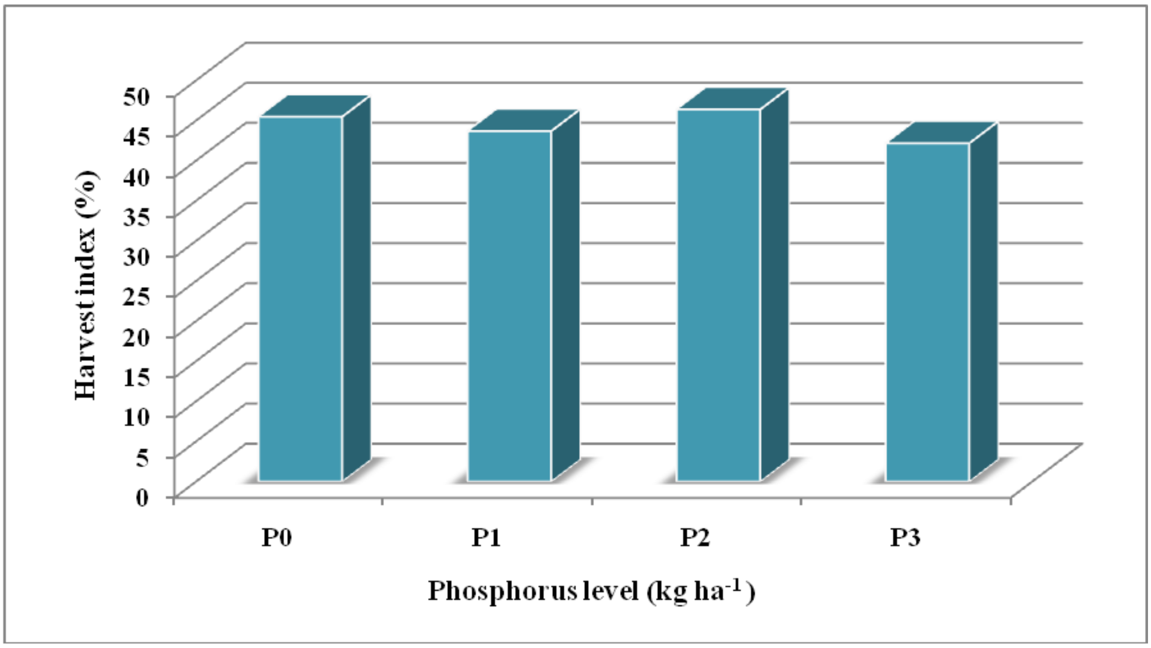

Figure 16. Effect of phosphorus on harvest index of hybrid Heera1 (SE = 1.80)

P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

4.4.3 Interaction of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus had significant effect on harvest index on hybrid rice (Table 6 and appendix IX). Among the treatment combination, N_4P_0 produced the highest harvest index (59.78%) followed by N_3P_2 (55.5%). The lowest value of harvest index was obtained from the treatment combination of $N_5P_{0.}$

Table 6. Grain yield, straw yield, biological yield and harvest index of hybrid Heera1 as influenced by nitrogen and phosphorus interaction

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
N_0P_0	5.17 e	5.67 f	10.83 f	47.37 b-d
N_0P_1	6.00 b-e	5.50 f	11.5 ef	51.36 bc
N_0P_2	4.83 e	7.83 c-f	12.67 d-f	39.57 cd
N_0P_3	5.33 de	6.67 ef	12.00 d-f	40.71 b-d
N_1P_0	6.00 b-e	7.50 d-f	13.50 c-f	44.61 b-d
N_1P_1	5.67 c-e	9.17 b-f	14.83 c-f	39.23 cd
N_1P_2	7.17 a-e	5.83 f	13.00 c-f	55.28 ab
N_1P_3	5.00 e	8.17 b-f	13.17 c-f	38.10 cd
N_2P_0	9.17 a	12.83 a-c	22.00 ab	42.03 b-d
N_2P_1	9.17a	12.33 a-d	21.50 ab	42.86 b-d
N_2P_2	9.83 a	15.00 a	24.83 a	39.21 cd
N_2P_3	9.50 a	13.17 ab	22.67 ab	42.40 b-d
N_3P_0	7.67 a-e	9.17 b-f	16.83 b-f	46.59 a-d
N_3P_1	4.83 e	8.00 c-f	12.83 d-f	40.11 b-d
N_3P_2	7.67 a-e	6.33 ef	14.00 c-f	55.05 ab
N_3P_3	6.00 b-e	8.17 b-f	14.17 c-f	42.27 b-d
N_4P_0	9.00 ab	6.17 ef	15.17 c-f	59.78 a
N_4P_1	8.67 a-c	9.50 b-f	18.17 b-d	49.34 a-c
N_4P_2	8.83 ab	8.83 b-f	17.67 b-e	50.28 a-c
N_4P_3	7.83 a-e	8.83 b-e	16.67 b-f	47.59 a-d
N_5P_0	5.50 de	11.17 a-e	16.67 b-f	32.56 d
N_5P_1	8.33 a-d	13.17 ab	21.5 ab	39.33 cd
N_5P_2	7.17 a-e	12.17 a-d	19.33a-c	39.03 cd
N_5P_3	7.00 a-e	10.17 a-f	17.17 b-f	41.99 b-d
SE	**2.64**	**4.21**	**5.38**	**12.67**
CV (%)	**22.34**	**27.58**	**19.85**	**17.22**

N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (75 kg N ha^{-1}), N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}, P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}

Chapter 5

Summary and conclusion

SUMMARY AND CONCLUSIONS

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during November, 2010 to December, 2011 with a view to finding out the influence of nitrogen and phosphorus on growth and yield of hybrid rice. The experimental treatments included five levels of nitrogen (N_0 = 0 kg N ha^{-1}, N_1 = 80 kg N ha^{-1}, N_2 = Urea super granules (2.7 g) @ 75 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}, N_4 = 160 kg N ha^{-1}, N_5 = 200 kg N ha^{-1}) and four levels of phosphorus (P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 30 kg P_2O_5 ha^{-1}, P_2 = 50 kg P_2O_5 ha^{-1}, P_3 = 70 kg P_2O_5 ha^{-1}). The experiment was laid out in a split plot design with three replications having nitrogen application in the main plots and phosphorus in the sub-plots. There were 24 treatments combinations. The total numbers of unit plots were 72. The size of unit plot was 5 m x 2.5 m = 12.5 m^2.

Urea was applied in three equal splits at 10, 35 and 55 DAT. On the other hand, USG (2.7 g) was placed manually at 5-10 cm depth of soil in the middle of four consecutive hills of two adjacent rows. Seedlings were transplanted with 25 cm spacing between lines and 15 cm spacing between hills. Intercultural operations such as gap filling, weeding, water management and pest management were done as and when necessary. Maturity of crop was determined when 90% of the grains become golden yellow in color. An area of 3 m^2 was harvested from centre of each plot avoiding the border effect. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12 %. Straw was also sun dried properly.

The data on crop growth characters like plant height, number of tillers hill^{-1} and leaf area index were recorded at 15, 30, 45, 60, 75. 90, 105DAT and at harvest and dry mater were recorded at 30 DAT, 60 DAT, 90 DAT and at harvest in the field and yield as well as yield contributing characters like number of effective tillers hill^{-1}, panicle length, number of grains panicle^{-1}, percent filled and unfilled grains, 1000-grain weight, grain and straw yield were recorded after harvest. Finally grain and straw yields plot^{-1} were recorded and converted to t ha^{-1} and analyses using the IRRISTAT (Version 4.0, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by Duncan's Multiple Range Test (DMRT).

A significant variation in plant height at different plant ages was observed due to nitrogen level variation. Plant height increased progressively up to maturity. At 15 and 30 DAT highest plant height was observed with 120 kg N ha^{-1} (N_3) but N_5 (200 kg N ha^{-1}) produced maximum plant height at 45 DAT. USG @ 75 kg N ha^{-1} (N_2) produced highest plant height at 60, 75, 90, 105 DAT and at maturity. At harvest the tallest plant (96.74 cm) was observed with N_2 and shortest (87.02 cm) with control treatment. Phosphorus had no significant variation in plant height. The treatment combination N_2P_2 produced highest plant height (98.72 cm) at harvest.

Tillers hill^{-1} increased up to 75 DAT and then decline irrespective of treatment variables. In all the growth stages, maximum tillers hill^{-1} were observed with N_2 (USG @ 75 kg N ha^{-1}) which was followed by 200 kg N ha^{-1} (N_5).

Phosphorus had no significant variation in tiller hill^{-1}. The treatment combination N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) produced highest tiller hill^{-1} significantly at all growth stages.

Leaf area index increased with age reaching a peak at 90 DAT and there after decline. Maximum (7.23) LAI was found at 90 DAT due to the effect of USG @ 75 kg N ha^{-1} which was followed by N_5 (200 kg N ha^{-1}). However, after 90 DAT, LAI declined due to senescence of leaves with the progress to maturity. There was no significant effect of phosphorus on leaf area index at all growth stages.

Accumulation of dry matter increased progressively over time attaining the highest at harvesting time. Application of N_2 (USG @75 kg N ha^{-1}) produced highest dry matter weight which was followed by N_5 (200 kg N ha^{-1}). Phosphorus had no significant variation on accumulation of total dry matter.

Application of USG @ 75 kg N ha^{-1} produced the highest effective tiller hill^{-1} (13.63) and lowest (10.12) by control. Application of 30 kg P_2O_5 ha^{-1} produced the highest effective tillers (12.41) and lowest by $P_{0.}$ Treatment combination N_2P_1 (USG @ 75 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) produced highest number of effective tillers (15.25) and lowest by N_0P_0.

Nitrogen and phosphorus had positive role in increasing the panicle length. Application of USG @ 75 kg N ha^{-1} (N_2) produced longest panicle (24.29 cm) and shortest with control. Application of 30 kg P_2O_5 ha^{-1} (P_2) produced highest panicle length (23.98 cm) and the treatment combination N_2P_1 produced longest panicle (25.09) while shortest with N_0P_0.

USG @ 75 kg N ha^{-1} (N_2) produced highest number of filled grain $panicle^{-1}$ (154.7). Application of 70 kg P_2O_5 ha^{-1} (P_3) produced highest (146.6) filled grains. Among the treatment combination N_2P_3 produced highest filled grains. Maximum unfilled grain was observed with control treatment of N and P whereas N_0P_0 produced maximum unfilled grain. Highest total grain per panicle (158.2) was obtained from N_2 application. Application of 70 kg P_2O_5 ha^{-1}(P_3) produced highest total grain per panicle whereas treatment combination of N_2P_1 and N_2P_3 produced highest (163.2 and 162.8 respectively) total grain.

Significantly highest 1000 grain weight (29.35 g) was observed with N_2 (USG @ 75 kg N ha^{-1}) and lowest (27.86 g) with N_0. In case of P, the highest 1000 grain (28 g) was obtained with P_3 (70 kg N ha^{-1}) and lowest with control (no phosphorus). The highest 1000 grain weight (29.65 g) was obtained with combination treatment of N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) and lowest (27.53 g) with N_0P_0. USG @ 75 kg N ha^{-1} (N_2) produced the highest grain yield (9.42 t ha^{-1}) which was statistically at par with 160 kg N ha^{-1} (N_4). The lowest grain yield was observed with N_0. Phosphorus did not show any significant response in grain yield. Among the different treatment combination N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) produced the highest grain yield (9.83 t ha^{-1}).

Significant variation in straw yield was observed when N was applied but there was no significant variation among the P levels. The highest straw yield (13.33 t ha^{-1}) was observed with N_2 which was statistically similar with N_5 (200 kg N ha^{-1}). Among the treatment combination, N_2P_2 produced the highest straw yield (15 t ha^{-1}).

Significantly the highest biological yield (22.75 t ha^{-1}) was observed with N_2 (USG @ 75 kg N ha^{-1}) and the lowest (11.75 t ha^{-1}) with $N_{0.}$ The treatment combination of N_2P_2 (USG @ 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}) produced the highest biological yield followed by N_2P_3 (USG @ 75 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1}) and the lowest with N_0P_0. Harvest index was highest (51.75%) in N_4 (160 kg N ha^{-1}) followed by N_3 (120 kg N ha^{-1}) (46%) and the lowest harvest index (38.23%) in N_5 (200 kg N ha^{-1}).

It could be concluded that application of nitrogen and phosphorus is necessary for raising yield of hybrid rice. Application of USG @ 75 kg N ha^{-1} produced the highest grain yield (9.42 t ha^{-1}). The second highest grain yield (8.58 t ha^{-1}) was found with 160 kg N ha^{-1} which was statistically at par with USG @ 75 kg N ha^{-1}. Application of 50 kg P_2O_5 ha^{-1} produced the highest grain yield (7.58 t ha^{-1}). Results suggest that application of USG @ 75 kg N ha^{-1} along with 50 kg P_2O_5 ha^{-1} would be needed for obtaining higher growth and yield for hybrid Heera1. The second highest growth and yield was obtained from 160 kg N ha^{-1} along with 50 kg P_2O_5 ha^{-1}. However, to reach a specific conclusion and recommendation, more research work on hybrid Heera1 with nitrogen and phosphorus should be done over different Agro-ecological zones.

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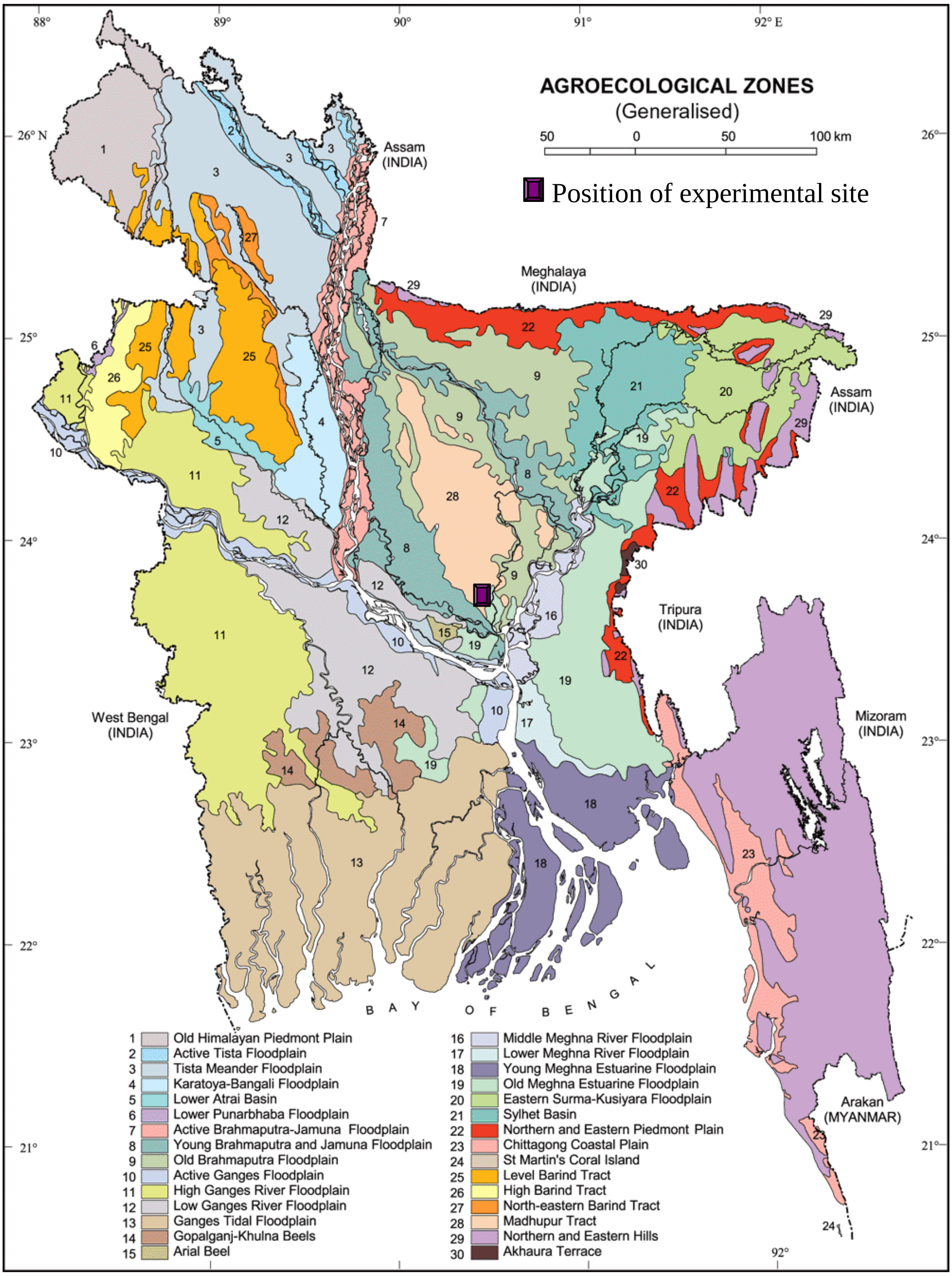
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Weather data, 2010-11, Dhaka

Month	Average RH (%)	Average Temperature (ºC)		Total Rainfall (mm)	Average Sunshine hours
		Min.	Max.		
October	78	23.8	31.6	172.3	5.2
November	77	19.2	29.6	34.4	5.7
December	69	14.1	26.4	12.8	5.5
January	68	12.7	25.4	7.7	5.6
February	68	15.5	28.1	28.9	5.5
March	64	20.4	32.5	65.8	5.2
April	69	23.6	33.7	165.3	4.9
May	81	24.5	32.9	339.4	4.7

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207.

Appendix III. Physiochemical properties of the initial soil

Characteristics	Value
Partical size analysis.	
% Sand	25.68
% Silt	53.85
% Clay	20.47
Textural class	silty-loam
pH	7.1
Organic carbon (%)	0.31
Organic matter (%)	0.54
Total N (%)	0.027
Phosphorus(µg/g soil)	23.66
Exchangeable K (me/100 g soil)	0.60
Sulphur (µg/g soil)	28.43
Boron (µg/g soil)	0.05
Zinc (µg/g soil)	2.31

Source: Soil Resources Development Institute (SRDI), Dhaka-1207

Appendix IV. Means square values for plant height (cm) of hybrid Heera1 at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting							
		15	30	45	60	75	90	105	At harvest
Replication	2	4.95	3.29	3.03	88.74	148.16	368.96	313.59	265.15
Nitrogen (N)	5	15.71*	11.13*	11.59*	85.84*	294.14*	317.47**	131.48**	134.42**
Error (a)	10	4.54	12.79	6.91	24.28	57.28	49.83	21.61	9.19
Phosphorus (P)	3	2.57NS	6.05NS	5.76NS	24.26NS	8.75NS	27.82NS	28.53NS	2.60NS
N x P	15	5.53*	4.60*	8.03*	16.09*	15.26*	27.14*	9.28*	9.29*
Error (b)	36	5.26	5.49	5.22	14.65	13.21	22.08	14.09	13.52

*Significant at 5% level

**Significant at 1% level

NS=Non Significant

Appendix V. Means square values for tiller hill^{-1} of hybrid Heera1 at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting					
		45	60	75	90	105	At harvest
Replication	2	4.43	6.53	51.08	12.99	12.57	0.37
Nitrogen (N)	5	0.63NS	17.32*	156.28**	114.55**	98.86**	41.14**
Error (a)	10	1.08	3.34	11.77	2.79	5.11	4.99
Phosphorus (P)	3	0.04NS	1.81NS	12.36NS	3.21NS	2.44NS	6.36NS
N x P	15	0.92NS	2.57*	7.89*	6.68*	4.69*	5.06*
Error (b)	36	0.69	2.85	7.18	3.99	3.41	3.35

*Significant at 5% level

**Significant at 1% level

NS=Non Significant

Appendix VI. Means square values for LAI of hybrid Heera1 at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting							
		15	30	45	60	75	90	105	At harvest

Replication	2	0.00	0.00	0.002	0.048	0.286	5.135	4.360	7.230
Nitrogen (N)	5	0.00^{NS}	0.003*	0.056**	0.218**	2.219*	9.508**	13.672**	8.105**
Error (a)	10	0.00	0.001	0.010	0.035	0.660	1.447	0.665	1.569
Phosphorus (P)	3	0.00^{NS}	0.000^{NS}	0.011^{NS}	0.019^{NS}	0.015^{NS}	1.333^{NS}	1.926^{NS}	0.258^{NS}
N x P	15	0.00	0.000*	0.009*	0.077*	0.240*	0.733*	1.383*	0.433*
Error (b)	36	0.00	0.001	0.009	0.039	0.237	0.777	1.087	0.354

*Significant at 5% level

**Significant at 1% level

NS=Non Significant

Appendix VII. Means square values for total dry matter weight of hybrid Heera1 at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting			
		30	**60**	**90**	**At harvest**
Replication	2	0.001	5.730	128.387	425.784
Nitrogen (N)	5	0.006*	11.372**	614.264**	998.535*
Error (a)	10	0.003	0.860	75.079	261.115
Phosphorus (P)	3	0.002^{NS}	3.582^{NS}	53.165^{NS}	161.999^{NS}
N x P	15	0.004*	1.877*	37.835*	105.726*
Error (b)	36	0.003	2.061	41.234	116.853

*Significant at 5% level

**Significant at 1% level

NS=Non Significant

Appendix VIII. Means square values for yield contributing characters of hybrid Heera1

Sources of variation	DF	Means square values					
		Effective tillers (No.)	**Panicle length (cm)**	**Filled grains panicle^{-1} (No.)**	**Unfilled grains panicle^{-1} (No.)**	**Total grains panicle^{-1} (No.)**	**1000 grains weight (g)**
Replication	2	1.75	0.43	75.69	1.14	65.41	0.39

Nitrogen (N)	5	20.07^{**}	5.37^{**}	1102.48^{*}	3.13^{*}	1034.71^{*}	3.39^{**}
Error (a)	10	3.39	0.82	450.05	1.39	477.36	0.44
Phosphorus (P)	3	10.85^{*}	27.64^{**}	296.91^{NS}	7.03^{**}	269.83^{NS}	1.30^{**}
N x P	15	1.71^{**}	0.73^{**}	172.41^{*}	1.62^{*}	176.36^{*}	0.23^{**}
Error (b)	36	3.08	0.98	207.00	0.97	212.47	0.24

*Significant at 5% level

**Significant at 1% level

NS = Non Significant

Appendix IX. Means square values for grain yield, straw yield, biological yield and harvest index of hybrid Heera1

Sources of variation	**DF**	**Means square values**			
		Grain yield (t ha^{-1})	**Straw yield (t ha^{-1})**	**Biological yield (t ha^{-1})**	**Harvest index (%)**
Replication	2	0.524	24.266	31.774	163.558
Nitrogen (N)	5	29.53^{*}	85.589^{*}	189.147^{**}	246.030^{*}
Error (a)	10	6.703	19.262	33.595	130.311
Phosphorus (P)	3	1.991^{NS}	2.324^{NS}	5.213^{NS}	63.700^{NS}
N x P	15	2.421^{**}	5.357^{**}	6.738^{**}	98.334^{*}
Error (b)	36	2.544	6.470	10.546	58.551

*Significant at 5% level

**Significant at 1% level

NS = Non Significant

LIST OF PLATES

Plate 1. Field view after transplanting

Plate 2. Field view at tillering stage

Plate 3. Field view of treatment difference

Plate 4. Field view at ripening stage