INFLUENCE OF PHOSPHORUS FERTILIZATION ON DIFFERENT HYBRID MAIZE VARIETIES

A Thesis

By

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Examination Roll No. 08-3185
Semester: July-December, 2009
Registration No. 08-3185

Submitted to the Department of Soil Science
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Sher-e-Bangla Agricultural University
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CERTIFICATE

This is to certify that thesis entitled "*Influence of phosphorus fertilization on different hybrid maize varieties*" submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207 in partial fulfillment of the requirements for the degree of **Master of Science** (MS) in **Soil Science** embodies the result of a piece of *bonafide* research work carried out by **Md. Bulbul Ahmmed**, Registration No. **08-3185** 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 by him.

Supervisor

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Place: Dhaka, Bangladesh

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Dedicated to

My Beloved Parents

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The author

ABSTRACT

A field experiment was conducted at the central research farm of Bangladesh Agricultural Research Institute, Gazipur during the period from November 2008 to April 2009 to investigate the effect of different levels of phosphorus application on growth, yield attributes and yield of hybrid maize. The soil belongs to the Chhiata soil series under AEZ-28 (Madhupur Tract). The soil is clay loam having pH 6.20, organic carbon 0.99%, total nitrogen 0.052%, available phosphorus 13.1 ppm, exchangeable potassium 0.39 me/100 g soil and available sulphur 8.51 ppm. The experiment comprised four hybrid maize varieties *viz*., BARI hybrid maize-2, BARI hybrid maize-3, BARI hybrid maize-5 and BARI hybrid maize-7 and four levels of phosphorus *viz*. 0, 30, 60 and 90 kg ha^{-1} along with a blanket dose of $N_{250}K_{100}S_{40}Mg_{10}Zn_5$ B_2 kg ha^{-1} and cowdung 5 t ha^{-1}. Phosphorus was used as triple super phosphate. The experiment was laid out in two factors randomized complete block design with three replications. Phosphorus significantly increased morphological, yield attributes and grain yield of maize up to 60 kg P ha^{-1} and at the highest level of application, yield was declined. The highest grain yield (7.62 t ha^{-1}) was observed at 60 kg P ha^{-1} treatment. Phosphorus increased the grain yield by 21.7-54.3% over the control. BARI hybrid maize-7 showed the highest grain yield (6.81 t ha^{-1}). However, from regression analysis, the optimum dose of phosphorus was found to be 73, 86, 70 and 78 kg ha^{-1} for BARI hybrid maize-2, BARI hybrid maize-3, BARI hybrid maize-5 and BARI hybrid maize-7, respectively for maximizing the yield of maize. The P uptake increased with increasing rate of P application in all the four tested varieties. Phosphorus showed a positive balance in all treatments in the study area for hybrid maize production. Considering the economic returns, phosphorus @ 60 kg ha^{-1} along with a blanket dose of $N_{250}K_{100}S_{40}Mg_{10}Zn_5$ B_2 kg ha^{-1} and cowdung 5 t ha^{-1} appeared to be the best-suited dose which may be recommended for maximizing the yield of hybrid maize in the AEZ-28.

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INTRODUCTION

CHAPTER I
INTRODUCTION

Maize (*Zea mays* L.), after rice and wheat, is the most important cereal crop in Bangladesh. It can be grown throughout the year because of its photo-insensitiveness. Maize is a unique crop because of its versatile use and low cost per unit of production (Iqbal, 2000). It has gained much popularity among the farmers of Bangladesh because of three reasons; (i) its yield is high, (ii) it has high protein content and (iii) it has good use as poultry feed and also in bakery. Maize grains have high nutritive value containing 66.2% starch, 11.1% protein, 7.12% oil and 1.5% minerals (Chowdhury and Islam, 1993).

Maize has a high potentiality with a wider range of climatic adaptability. The agro-climatic conditions of Bangladesh are favourable for maize cultivation round the year. Pest and disease infestations are less in this crop. Its water requirement is less compared to rice and wheat. So there is ample scope for expansion of maize growing area in Bangladesh.

Maize cultivation has become very popular and the crop is widely grown in many countries in the world. In recent times, maize production in Bangladesh exhibited robust performance as farmers brought more area under maize cultivation, attracting by lower production cost, encouraging prices and increasing domestic demand particularly for the growing poultry feed industry. Both the area and production of maize have been increasing at a tremendous rate for the last four years (BBS, 2010). Due to the high yield potentiality and versatile uses, almost year round growth ability and higher per hectare yield than other cereals, area and production of maize is increasing day by day in our country. However, hybrid maize is well known for its high demand for plant nutrients and other production inputs. Fertilizer is the vital input which plays a significant role in exploring the highest yielding varieties of hybrid maize. The farmers have been indoctrinated with the belief that all conditions required for maximum performance of hybrid maize have to be fulfilled to letters before the desired economic returns can be obtained. This extra production cost discourages most farmers engaging in hybrid maize production in the country.

The yield of maize, however, varies from variety to variety, location to location and also depends on the availability of essential factors such as soil nutrient status and application of fertilizers (Amanullah *et al.*, 2010). The response of different varieties of hybrid maize to different nutrients is not similar. Among the essential plant nutrients, maize is very responsive to phosphorus (P) other than nitrogen (N). Phosphorus is a vital plant nutrient and a major yield determining-factor required for maize production. Grain yield of maize is significantly correlated with P fertilization. Maize is an exhaustive crop. It removes more nutrients from the soil at a deeper soil depth. The results of various fertilizer experiments carried out in Bangladesh have led to fertilizer recommendations that gave blanket nutrient requirement for maize in ecologies having varying soil conditions and under varying levels of soil management (FPDD, 1990).

Maize yields in P deficient areas are low and unstable. Soils in these crop lands are further deficient in nitrogen (N). Although numerous soil fertility management strategies have shown significant maize yield increases, the prices of fertilizers inputs are unaffordable to small holder farmers; hence this technology is not easy to be adopted by farmers (Obura *et al.*, 2004). Farmers, however, accept high quality seed, the relative high unit cost of phosphorus fertilizers, coupled with the widespread deficiency and fixation constraints require the development of technologies that can make most efficient use of applied phosphorus in the soils. Keeping these views in mind, we target the identification of P efficient maize varieties that are tolerant to P deficiency. This may be assured as a positive avenue towards low cost technology adoption.

Therefore, the study was undertaken with the following objectives:

(i) to evaluate the response of different hybrid maize varieties to phosphorus applications

(ii) to find out the optimum dose of P for maximization the yield of different hybrid maize varieties

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Phosphorus plays greater role on the growth and yield of maize. Extensive studies have been carried out by the researchers throughout the world on various cultural practices of maize. But the information regarding phosphorus application in hybrid maize is limited. Some of the relevant findings have been reviewed and presented in this chapter.

2.1 Functions of phosphorus in plant growth

Phosphorus is an essential plant nutrient element and involve in the supply and transfer of energy for all the biochemical processes in plants. It stimulates early root growth and development, encourages more active tillering and promotes early flowering, maturity and good grain development. It is essential component of deoxyribonucleic acid (DNA), the inheritance characteristics of living organisms (Miller and Donahue, 1997). It helps in carbohydrate, fat and protein metabolism and serves an important role in cell division (Marschner, 1998). Due to lack of phosphorous, cell division slows down, the leaf colour changes to dark green, stem becomes more slender, the whole plant becomes dwarf and heading and ripening is also inhibited (Gupta, 2007). An adequate supply of P early in the life of a plant is important for the development of its reproductive parts. An adequate supply of P is associated with greater straw strength in cereals (Moro *et al.*, 2008). Moreover, sufficient P nutrition in maize is essential for normal growth and development and also for production of optimum grain yield. Application of P significantly increased seed, stalk yield and protein content in oil seed crops. It increases nodules number in leguminous crops (Quiao *et al.,* 2007).

2.2 Effects of phosphorus application on maize

Phosphorus is a major limiting factor for production on many tropical and sub-topical soils (Kolawole *et al.,* 2010) as a result of high P fixation and/or nutrient mining in traditional land use systems. Phosphorus deficiency is so acute that plant growth ceases as soon as the phosphorus stored in the seed is exhausted in some soils of Bangladesh (Rahman, 2009). Consequently, the farmers require the addition of P fertilizers for producing even moderate yields. Numerous studies have shown that P fertilizers can significantly increase crop yield (Batiano *et al.,* 1995; Kolawole *et al.,* 2000; Haider, 2009). Crop response to P fertilizer application, however, depend on many factors such as soil characteristics, climate, tillage system, crop management and fertilizer management. It is, therefore, necessary to take these factors into consideration before embarking on P fertilization programme to improve fertilizer use efficiency and economic returns. In many parts of the country, large spatial variability in soil characteristics occurs within the short distances. Under such situation, it becomes inevitable that fertilizer recommendations should be site specific.

A field experiment was conducted by Haider (2009) at BAU experimental farm under AEZ 9 (Old Brahmaputra Floodplain) to know the effect of P levels (0, 30 and 60 kg ha^{-1}) and reported that yield attributing characters such as number of cobs per plant, number of grains cob^{-1} and 1000-grain weight, and grain and stover yields were significantly influenced by P and the highest yield was observed with 60 kg P ha^{-1}.

Zaman (2008) evaluated the effect of different levels of phosphorus (0, 30, 45 and 60 kg P ha^{-1}) and sulphur on the growth and yield of Hybrid maize and reported that all plant characters such as plant height, cob number, cob length, number of grains cob^{-1}, straw and grain yield and nutrients uptake increased significantly over control due to phosphorus application. The author further reported that 60 kg P ha^{-1} was the best for getting maximum yield of hybrid maize in Old Brahmaputra Floodplain soil. Similar result was also reported by Eva (2008) who reported that maximum yield of BARI hybrid maize-2 was recorded in 50 kg P ha^{-1}.

The use of suitable fertilizers in appropriate doses is considered one of the most important factors which could increase maize yield on per unit area basis (Sharar *et al.*, 2003). The use of balanced fertilizer can increase yield up to 50% (Zia *et al.*, 1991). Growth and grain yield of different maize varieties was increased with increase in N and P levels (Amold *et al.*, 1994). Similarly, Khan *et al.* (1999) observed significant effects of NPK application on plant height, number of cobs $plant^{-1}$, number of grains cob^{-1}, 100-grain weight, grain and biological yield. Ali *et al.* (2002) reported significant effect of NP application on grain yield while non-significant effect of N and P on harvest index. Ayub *et al.* (2002) observed significant effects of NP application on dry matter yield and individual plant characteristics such as plant height, diameter, number of leaves and leaf area $plant^{-1}$.

Babu and Seshaiah (2006) conducted an experiment to evaluate the effect of three levels of P (0, 30 and 60 kg P_2O_5 ha^{-1}) applied as single super phosphate (SSP) and phosphate rock (PR) and their mixture (1:1) on growth, yield and nutrient uptake in maize and reported that grain and straw yields increased with increased P levels irrespective of source. SSP was found to be more effective than PR.

Shivay and Kumar (2005) studied the effect of P (20, 40, 60 and 80 kg P_2O_5 ha^{-1}) and Zn fertilizer application on growth, yield attributes, yield and nutrient uptake in maize and reported that 60 kg P_2O_5 ha^{-1} in combination with 5 kg Zn ha^{-1} was found suitable for achieving greater productivity of maize. Phosphorus uptake by maize increased significantly with each successive increase in P up to the highest level (80 kg P_2O_5 ha^{-1}). Similar result was also reported by Hussaini *et al.* (2005) in maize.

Kumleh and Kavassi (2004) evaluated the effect of phosphorus application (0, 25, 50, 75 and 100 kg P_2O_5 ha^{-1}) on growth and yield of local maize variety and reported that growth and yield of maize influenced significantly due to P application. The application of 100 kg TSP ha^{-1} resulted in high dry matter and grain yield with the highest P uptake. Similar result was also reported by Dongarwar *et al.* (2003) who reported that the highest grain yield was recorded in 100 kg P_2O_5 ha^{-1} in maize.

Ummed *et al.* (2003) carried out an experiment in Uttar Pradesh, India to determine the effect of NPK (60:30:30, 120:60:60 and 180:90:90 kg ha^{-1}) on maize cv. Gautom and reported that the treatment 120:60:60 kg NPK ha^{-1} significantly increased the grain and straw yields over 60:30:30 kg NPK ha^{-1}. However, the highest grain and straw weight was recorded in 180:90:90 kg NPK ha^{-1}, but that showed non-significant difference with 120:60:60 kg NPK ha^{-1}. Singh (2003) conducted an experiment for three consecutive years to establish the relationship between plant P and grain yield of maize cv. Kalinga grown in red soil and found that grain yield had strong relationship with P uptake by straw and grain.

A field trial was conducted by Khan *et al.* (2005) to study the effect of different levels of phosphorus (0, 25, 50, 75 and 100 kg P_2O_5 ha^{-1}) on two maize cultivars under saline conditions and reported that plant height, number of cobs per plant, number of grains cob^{-1}, number of grains $plant^{-1}$, 1000-grain weight and grain yield increased significantly with phosphorus applications. The authors further reported that the maize plants fertilized with 75 kg P_2O_5 ha^{-1} performed better for grain weight cob^{-1}, number of grains cob^{-1} and 1000-grain weight over other levels. Amanullah *et al.* (2010) studied the effect of three doses of P (30, 60 and 90 kg P ha^{-1}) on growth and yield of maize and reported that the highest level of P enhanced phonological development, and increased ear length, number of cob $plant^{-1}$, number of grains cob^{-1}, grain weight, economic yield, shelling percentage and net return.

In a field experiment, growth and grain yield of maize cv. Golden as influenced by different NP combinations were studied by Sharar *et al.* (2003) and observed that the different NP combinations significantly influenced the plant height, cob bearing plants m^{-2}, number of cobs $plant^{-1}$, number of grains cob^{-1}, 1000-grain weight, grain yield and harvest index. The authors reported that the NP application at the rate of 130-180 kg ha^{-1} produced significantly higher grain yield than all other NP combinations.

Syed *et al.* (2002) reported that grain yield, stover yield and biological yield of maize were significantly affected by different P levels. The authors reported that 90 kg P ha^{-1} produced maximum number of cobs $plant^{-1}$, number of grains cob^{-1} which resulted the highest grain yield.

Maqsood *et al.* (2001) studied the effect of various levels of phosphorus (0, 30, 60 and 90 kg ha^{-1}) on growth and yield of maize cv. Golden and found that plant height and biological yield increased with increasing P rate. They further reported that yield attributes and grain yield was the highest in 90 kg P ha^{-1} which was statistically similar to 60 kg P ha^{-1}.

Pierre *et al.* (1990) studied the effect of P levels (0, 24, 40 and 80 kg P ha^{-1}) on growth and yield of maize (cv. Frances) and reported that plant growth and development as well as yield attributes increased with increasing P levels. Thanki *et al.* (1988) found that maize hybrid Ganga Safed-2 gave grain yields of 4.35, 5.33 and 5.72 t ha^{-1} for 0, 30 and 60 kg P_2O_5 ha^{-1}, respectively. Ali *et al.* (1986) studied the effect of different P levels (0-150 kg ha^{-1}) on maize and reported that grain yields increased with increasing P level and the highest grain yield observed in 150 kg P ha^{-1}. Similar result was also reported by Talukder *et al.* (1982) in maize. They reported that grain yield increased with increasing P levels up to 120 kg P_2O_5 ha^{-1}.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

In this chapter the details of different materials used and methodology followed for the study are described under the different heads.

3.1 Experimental site

The experiment was carried out at the Central Research Farm of Bangladesh Agricultural Research Institute, Gazipur during the period from 30 November 2008 to 07 April 2009. Geographically the experimental area is located at $24^{0}09''$ N latitude and $90^{0}25''$ E longitudes at the elevation of 8.2 m above the sea level. The experimental field was medium high land belonging to the Chhiata series of Grey Terrace Soil (AEZ-28, Madhupur Tract). The morphological characteristics of the land are presented in Table 3.1 and the physical and chemical characteristics of the soil are presented in Table 3.2.

Table 3.1. Morphological characteristics of the experiment field

Characters	BARI farm
Locality	BARI, Gazipur
Geographic position	24.09^{o} North Latitude 90.5^{o} East Longitude 8.2 m high above the mean sea level
Agro Ecological Zone (FAO and UNDP, 1988)	Madhupur Tract (AEZ-28)
General soil type	Shallow Grey Terrace Soil
Taxonomic soil classification: Order Sub-order Sub-group Soil series	 Inceptisols Aquept Aeric Albaquept Chhiata
Parent material	Madhupur terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above Flood level

Table 3.2. Physical and chemical characteristics of the soils

Characteristics	BARI farm
Mechanical fractions:	
% Sand (0.2-0.02 mm)	27.4
% Silt (0.02-0.002 mm)	33.3
%Clay (< 0.002 mm)	39.3
Textural class	Clay loam
Colour	Grey
Consistency	Sticky and mud when wet
pH (1:2.5 Soil-Water)	6.2
CEC (cmol kg^{-1})	18.4
Exchangeable K (meq/100 g)	0.39
Exchangeable Ca (meq/100 g)	3.20
Exchangeable Mg (meq/100 g)	1.34
Exchangeable Na (meq/100 g)	0.16
Organic C (%)	0.99
Total N (%)	0.052
Available P (mg kg^{-1})	13.1
Available S (mg kg^{-1})	8.51
Available Zn (mg kg^{-1})	1.52
Available Cu (mg kg^{-1})	0.66
Available Fe (mg kg^{-1})	1.68
Available Mn (mg kg^{-1})	3.1
Available boron (mg kg^{-1})	0.33

3.2 Climate and weather

The experimental field is under subtropical climate characterized by heavy rainfall during the month of April to September and scanty rainfall during October to March. The monthly means of daily maximum, minimum and average temperature, relative humidity, total rainfall and sunshine hours received at the experimental site during the period from November 2008 to April 2009 are presented in Table 3.3.

3.3 Collection of soil sample

Three composite soil samples were collected from a depth of 0-15 cm taking one from each block immediately before fertilizer application. Each composite sample was air dried and ground to pass through a 10 mesh sieve and stored in polythene bags for mechanical and chemical analysis.

Table 3.3 Average monthly rainfall, air temperature and relative humidity during the experimental period between November 2008 to April, 2009 at the BARI area, Gazipur

Month	Daily average air temperature (^0C)			Average Daily rainfall (mm)	Average Daily relative humidity (%)	Average daily sunshine (hrs)
	Maximum	Minimum	Average			
October	31.27	24.14	27.71	18.0	86.2	8.65
November	29.49	19.55	24.52	00.0	84.3	8.45
December	26.52	13.19	19.85	00.0	80.8	6.67
January	23.43	12.93	18.18	00.0	78.0	7.20
February	27.34	16.41	21.87	06.6	73.9	8.18
March	29.61	20.57	25.09	13.6	80.6	7.66
April	30.56	22.14	26.35	96.6	78.57	7.42

Source: Weather Yard, Department of Irrigation and Water Management, BARI, Gazipur

3.4 Materials of the experiment

3.4.1 Plant material

Four maize hybrid varieties viz., BARI hybrid maize-2, BARI hybrid maize-3, BARI hybrid maize-5 and BARI hybrid maize-7 were used as planting material in this experiment. The materials were collected from Plant Breeding Division, Bangladesh Agricultural Research Institute, Gazipur. Information about all these genotypes are described in Table 3.4.

Table 3.4. Main features of the experimental materials

Sl. No.	Variety	Origin/ sources	Main features
1.	BARI hybrid maize-2	BARI	It was released in 1995 for country wide cultivation and it is grown in all seasons. It requires 130-140 days to mature. The plant stature is medium. The 100-grain weight is 36.5 g. The average yield potential of this variety is 6.5 t ha^{-1}.
2.	BARI hybrid maize -3		
3.	BARI hybrid maize -5		
4.	BARI hybrid maize -7		

3.4.2 Treatments

The experiment comprised two factors:

Factor A: Four maize varieties *viz.*, BARI hybrid maize-2, BARI hybrid maize-3, BARI hybrid maize-5 and BARI hybrid maize-7

Factor B: Four levels of P *viz.*, 0, 30, 60 and 90 kg ha^{-1}

The treatment combinations for the experiment have been shown in Table 3.5 and the sources of nutrients have been presented in Table 3.6.

Table 3.5. Treatments and fertilizer dose

Treatments	Treatment combination	Fertilizer dose (kg ha^{-1})							
		N	P	K	S	Mg	Zn	B	Cowdung
T_1	BHM-2 + 0 kg P ha^{-1}	250	0	100	40	10	5	2	5000
T_2	BHM-2 + 30 kg P ha^{-1}	250	30	100	40	10	5	2	5000
T_3	BHM-2 + 60 kg P ha^{-1}	250	60	100	40	10	5	2	5000
T_4	BHM-2 + 90 kg P ha^{-1}	250	90	100	40	10	5	2	5000
T_5	BHM-3 + 0 kg P ha^{-1}	250	0	100	40	10	5	2	5000
T_6	BHM-3 + 30 kg P ha^{-1}	250	30	100	40	10	5	2	5000
T_7	BHM-3 + 60 kg P ha^{-1}	250	60	100	40	10	5	2	5000
T_8	BHM-3 + 90 kg P ha^{-1}	250	90	100	40	10	5	2	5000
T_9	BHM-5 + 0 kg P ha^{-1}	250	0	100	40	10	5	2	5000
T_{10}	BHM-5 + 30 kg P ha^{-1}	250	30	100	40	10	5	2	5000
T_{11}	BHM-5 + 60 kg P ha^{-1}	250	60	100	40	10	5	2	5000
T_{12}	BHM-5 + 90 kg P ha^{-1}	250	90	100	40	10	5	2	5000
T_{13}	BHM-7 + 0 kg P ha^{-1}	250	0	100	40	10	5	2	5000
T_{14}	BHM-7 + 30 kg P ha^{-1}	250	30	100	40	10	5	2	5000
T_{15}	BHM-7 + 60 kg P ha^{-1}	250	60	100	40	10	5	2	5000
T_{16}	BHM-7 + 90 kg P ha^{-1}	250	90	100	40	10	5	2	5000

Table 3.6. Source of nutrients with content

Nutrient elements	Source	nutrient content
Nitrogen (N)	Urea	46 % N
Phosphorous (P)	Triple super phosphate	20 % P
Potassium (K)	Muriate of potash	50 % K
Sulphur (S)	Gypsum	18 % S
Magnesium (Mg)	Magnesium sulphate	9.5% Mg
Zinc (Zn)	Zinc oxide	78 % Zn
Boron (B)	Boric acid	17% B

3.4.3 Experimental design and lay out

The experiment was laid out in a two factor randomized complete block design with three replications. The size of the unit plot was 4.0 m × 5.0 m. Distances between block to block and plot to plot were 1.0 m. Seeds were sown with a spacing of row to row 75 cm and seed to seed 25 cm and the seed rate was 25 kg ha^{-1}.

3.5 Land preparation

The land of the experimental site was first opened in 2nd week of November with power tiller. Later on, the land was ploughed and cross-ploughed three times followed by laddering to obtain the desirable tilth. The corners of the land were spaded and weeds and stubbles were removed from the field. The land was finally prepared on 30 November, 2008.

3.6 Fertilizer application

Urea, TSP, MP, Gypsum, Magnesium sulphate, Zinc sulphate and Boric acid were used as the sources of N, P, K, S, Mg, Zn and B, respectively. All P, K, S, Mg , Zn, B and cowdung and $1/3^{rd}$ N were applied at the time of final land preparation and the remaining $2/3^{rd}$ N was applied in two equal installments each at 30 and 60 days after sowing. The recommended blanket doses of K, S, Mg, B and Zn were applied at the time of final land preparation. The different doses of phosphorus were applied on plots according to treatments after developing layout of the experimental field and mixed with spading.

3.7 Sowing of seeds

Seeds were sown on the 30 November 2008 in the row by opening 3-4 cm deep furrows with a country plough and seeds were placed at 25 cm interval within a row. After sowing the seeds were covered with soil.

3.8 Gap filling

The seedling emergence complete within 6-8 DAS. Necessary gap filling was done 15 DAS.

3.9 Intercultural operations

Intercultural operations were done for ensuring and maintaining the normal growth of the crop. The necessary intercultural operations were done as and when required.

3.9.1 Weeding

The experimental plots were infested with some common weeds which were controlled by hand weeding three times at 30, 60 and 80 days after planting.

3.9.2 Irrigation

The crop was irrigated two times; first at 35 DAS and 2^{nd} at 70 DAS.

3.9.3 Insect and pest control

There was minor incidence of insect at silking stage at 105 DAS, but no disease incidence was noticed over the growing period. The crop field was sprayed with Dersban-50 at 105 DAS to control the insects and pests.

3.10 Sampling, harvesting, threshing, cleaning and processing

Maturity of crop was determined when about 90% grains become golden yellow. Five hills were randomly selected from each plot and tagged for recording necessary data. After sampling, the whole plot was harvested at maturity on 19 April, 2009. The harvested crop of each plot was bundled, tagged and then brought to the threshing floor. The cobs were separated from the harvested crop by hand. The harvested cobs were dried in sunlight, shelled and the grain cleaned properly. The plot wise grain and stover weight were recorded and converted into tons hectare^{-1}.

3.11 Data Collection

3.11.1 Morphological parameters

i) Plant height (cm): Plant height was taken to the length between the base of the plant to the tip of ear.

ii) Ear height (cm): Measurement was taken from basal node of the ear to the apex of ear.

iii) Cob length (cm): Length of ten randomly selected cobs from each of replication were measured and then divided by 10 (ten) to get single cob length in centimeter.

iv) Cob circumference (cm): Cob circumference was measured in centimeter along the middle part of the cob by the help of measuring tape of 10 (ten) randomly selected cobs and its average was calculated.

3.11.2 Yield and yield contributing characters

v) Number of cobs plant^{-1}: The total number of cobs plant^{-1} was recorded from 10 (ten) sample plants and then averaged.

vi) Number of grains cob^{-1}: Filled grains of 10 (ten) randomly selected cobs of each replication were counted and then the average number of grains for each cob was determined.

vii) Weight of 100-grain: One hundred clean sun dried grains were counted from the seed stock obtained from the sample plants and weighed by using electronic balance.

viii) Grain yield: The grains were separated from cob by threshing plot-wise and then sun dried and weighed. The grain weight was finally converted into tons ha^{-1}.

ix) Straw yield: Straw obtained from each unit plot was sun dried and weighed and then converted into tons $hectare^{-1}$.

3.12 Soil analysis

3.12.1 Soil collection

The initial soil sample was collected before land preparation from the plough depth (0-15 cm). The samples were air dried, ground, mixed thoroughly and sieved through 10 mesh sieve. The composite soil sample was stored in a clean plastic container for physical and chemical analyses. The initial soil sample was analysed for physical and chemical properties in the laboratory of the Soil Science Division, Bangladesh Agricultural Research Institute, Gazipur. The properties studied include soil texture, pH, organic matter, total N and available P, K, S, Ca, Mg, and Zn content. The soil samples were analyzed following the standard methods.

3.12.2 Particle size analysis

The particle size analysis was done by hydrometer method as described by Piper (1950) and the textural class was determined by plotting the results of % sand, % silt and % clay to the Marshall's Triangular Co-ordinate following the USDA system.

3.12.3 Soil pH

The soil pH was measured with the help of a glass electrode pH meter using soil water suspension ratio of 1: 2.5 as described by Jackson (1962).

3.12.4 Organic matter

Organic carbon in soil sample was determined volumetrically by wet oxidation method of Walkley and Black (1934). The underlying principle is to oxidation of organic matter with an excess of N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with N $FeSO_4$ solution. The amount of soil organic matter was calculated by multiplying the percent value of organic carbon with the Van Bemmelen factor, 1.73 (Piper, 1950).

3.12.5 Total nitrogen

Total nitrogen content in soil was determined by Micro Kjeldahl method. Five gram soil was taken in a 800 ml Kjeldahl flask and then 20 ml concentrated H_2SO_4 and 5 g catalyst mixture (100:10:1, K_2SO_4:$CuSO_4$:Se) were added to it and the digestion was started. When green colour appeared and white fumes produced around the neck indicating the completion of digestion. Twenty five ml 4% boric acid was taken in a 500 ml Erlenmeyer flask and drops of indicator was added to it. The flask was placed in the distillation set, so that the end of the condenser remained below the surface of the boric acid solution. After cooling the Kjeldahl flask, 120 ml of distilled water was added and 4-5 glass beads were taken in to the flask. Holding the distillation flask at 45 ^{0}C, 100 ml 40% NaOH was poured down to the neck, so the alkali reached the bottom of the flask without mixing the digest and it was attached as quickly as possible to the distillation set and then distillation was started. When about 150 ml of distillate was collected, distillation was over. Then the distillate was titrated against H_2SO_4. At the end point green colour of the solution changed to blue. A blank titration was conducted following the same procedure stated above.

3.12.6 Available phosphorus

Available soil phosphorus was determined by Olsen method (Olsen *et al.,* 1954). Five g soil was taken in a 250 ml conical flask. Then a little of carbon black and 100 ml 0.5M $NaHCO_3$ were added to it. The content was then shaken for 30 minutes on a horizontal mechanical shaker and were filtered through Whatman No. 42 filter paper. Later on, 5 ml of extract was taken into a 50 ml volumetric flask followed by 4 ml of sulphomolybdate solution and distilled water up to the volume of 45 ml. A few drops of stannous chloride solution were added and finally the volume was made up to the mark with distilled water and allowed to stand for 15 minutes for complete colour development. The readings were taken with the help of a spectrophotometer at 660 nm wave length.

3.12.7 Exchangeable potassium

Exchangeable potassium and sodium was determined with the help of flame emission spectrophotometer using potassium and sodium filter. The soil was extracted with neutral 1N ammonium acetate. The extracted sample was aspirated into a gas flame.

The air pressure was fixed at 10 psi. Percent emission was recorded following the method outlined by Ghosh *et al.* (1983).

3.12.8 Exchangeable Ca and Mg

Calcium and magnesium were determined by KCl extractable method.

3.12.9 Available sulphur

Available S content of soil was determined by extracting the soil with 0.15% $CaCl_2$ solution. The extractable sulphur content was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelength. The extraction method was described by Page *et al.* (1982).

3.12.10 Micronutrients

Cupper, iron, manganese and zinc were determined by $NaHCO_3$ extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method.

3.13 Plant sample analysis

The plant samples were collected from the experimental field and analyzed for P content only. Grain and straw samples were dried in oven at 65 ^{0}C for 48 hours and then ground by grinding machine to pass through a 20 mesh sieve. The grinding plant material (grain and straw) were stored in small paper bags and placed in a desiccator.

Determination of phosphorus: Plant samples were wet-digested with nitric-perchloric acid for the determination of phosphorus. An amount of 0.5 g oven dry ground sample was taken in a digestion flask. 10 ml di-acid mixture (HNO_3:$HClO_4$ in the ratio of 2:1) was added into the flask and the flask was allowed to stand for some time and followed by heating to boiling. Heating was continued until the digest was clear and colourless. After cooling, the content was transferred to a 50 ml volumemetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in the similar manner. Phosphorus was determined by using spectrophotometer as done in soil analysis using 2 ml of digest from 50 ml extract.

Phosphorous uptake: After chemical analysis of straw and grain samples, the P uptake was calculated from the nutrient content and yield of maize crop by the following formula:

$$\text{Nutrient uptake} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg ha}^{-1}\text{)}}{100}$$

3.14 Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) and the mean differences were separated by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C.

CHAPTRE IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The results of the study regarding the effect of phosphorous on the yield component and yield of different hybrid maize varieties have been presented with possible interpretations in this chapter.

4.1 Effect of phosphorus rate, variety and their interaction on morphological characters of hybrid maize varieties

4.1.1 Plant height

Mean effect of P showed significant (≤ 0.05) increase in plant height irrespective of varieties (Table 4.1). Results showed that plant height increased with increasing phosphorus rate up to 90 kg P ha^{-1}. The tallest plant was recorded in 90 kg P ha^{-1} (175.1 cm) followed by 60 kg P ha^{-1} (169.8 cm) with same statistical rank. In contrast, the phosphorous at the rate of 0 kg ha^{-1} (T_1) had the shortest plant height (147.7 cm). This result indicates that phosphorous has tremendous effect on growth and development in hybrid maize. This result is in agreement with that of Eva (2008) who reported that plant height increased with increasing phosphorus rate of hybrid maize till 80 kg P ha^{-1}. Similar result was also reported by BARI (2009) in maize that plant height increased with increasing phosphorus levels up to 90 kg P ha^{-1}.

The plant height varied significantly due to variety (Table 4.1). The tallest plant was observed in BARI hybrid maize-7 (174.8 cm) followed by BARI hybrid maize-2 (165.5 cm). The shortest plant was observed in BARI hybrid maize-3 (156.1 cm).

Genotypic variations in plant height were also observed by Begum (2008) in hybrid maize which supported the present findings.

Table 4.1. Main effect of phosphorus and variety on morphological characters of hybrid maize varieties

Treatments	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob circumference (cm)
Phosphorus level (kg ha^{-1})				
0	147.7 c	70.81 c	17.05 c	14.40 b
30	165.1 b	78.41 bc	18.57 bc	15.21 ab
60	169.8 ab	85.76 ab	20.76 a	15.91 a
90	175.1 a	91.48 a	20.05 ab	15.72 a
F-test	**	**	**	**
Variety				
BARI hybrid maize-2	165.5 b	79.88 b	20.11 a	15.14 ab
BARI hybrid maize-3	156.1 b	75.77 b	18.04 b	14.66 b
BARI hybrid maize-5	161.3 b	79.13 b	18.85 b	15.75 a
BARI hybrid maize-7	174.8 a	91.68 a	18.52 b	15.78 a
F-test	**	**	**	**
CV (%)	4.89	8.72	7.40	5.72

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; ** indicate significance at 1% level of probability.

The interaction effect of phosphorus and variety on plant height was found statistically significant (Table 4.2). The highest plant height (190.9 cm) was recorded in the treatment combination of BARI hybrid maize-7 with 90 kg P ha^{-1} and the lowest (135.5 cm) was recorded in the treatment combination of BARI hybrid maize-5 with 0 kg P ha^{-1}.

4.1.2 Ear height

Different levels of phosphorus application on hybrid maize had significant effect on ear height (Table 4.1). Results revealed that ear length was greater in phosphorus applied plots than control plots (Table 4.1). Result further revealed that ear height increased with increasing phosphorus level. The maximum ear length (91.5 cm) was recorded in 90 kg P ha^{-1} followed by 60 kg P ha^{-1} (85.8 cm) with same statistical rank. The minimum ear length (70.8 cm) was recorded in control plant where no phosphorus was applied. Amanullah *et al.* (2010) observed that application of phosphorous increased panicle length of rice that supported the present experimental result.

In case of varieties, the ear length varied significantly (Table 4.1). The highest ear length (91.48 cm) was recorded in BARI hybrid maize-7 which was significantly greater than other varieties. In contrast, BARI hybrid maize-3 produced the lowest ear length (75.77 cm). BARI (2007) reported that among the released varieties, BARI hybrid maize-7 produced the longest ear that supported the present experimental result.

Table 4.2. Interaction effect of variety and phosphorus level on morphological characters in hybrid maize

Interaction of variety and P rate (kg ha^{-1})	Plant height (cm)	Ear heigh (cm)	Cob length (cm)	Cob circumference (cm)
BHM-2 × 0 kg P ha^{-1}	156.0 de	70.0 d	16.93 d	14.77 b
BHM-2 × 30 kg P ha^{-1}	166.2 c	75.0 d	19.53 bc	14.87 b
BHM-2 × 60 kg P ha^{-1}	169.6 bcd	86.5 abc	22.23 a	15.57 ab
BHM-2 × 90 kg P ha^{-1}	170.1 bcd	87.9 abc	22.23 a	15.37 ab
BHM-3 × 0 kg P ha^{-1}	144.1 f	64.4 e	17.23 c	14.03 c
BHM-3 × 30 kg P ha^{-1}	155.6 ef	73.9 d	18.63 b	14.57 bc
BHM-3 × 60 kg P ha^{-1}	160.1 e	77.7 cd	19.13 b	15.43 ab
BHM-3 × 90 kg P ha^{-1}	164.6 cd	87.2 ab	19.27 b	14.80 b
BHM-5 × 0 kg P ha^{-1}	145.5 g	67.7 d	17.33 c	15.0 ab
BHM-5 × 30 kg P ha^{-1}	166.3 cd	71.0 d	18.33 bc	15.57 ab
BHM-5 × 60 kg P ha^{-1}	168.6 cd	83.2 bc	21.33 a	16.40 ab
BHM-5 × 90 kg P ha^{-1}	175.0 bc	94.5 ab	19.90 b	16.0 ab
BHM-7 × 0 kg P ha^{-1}	155.3 e	81.1 c	16.70 d	14.90 b
BHM-7 × 30 kg P ha^{-1}	172.2 bc	93.7 ab	17.77 c	15.83 ab
BHM-7 × 60 kg P ha^{-1}	180.9 ab	95.6 a	20.33 ab	16.23 a
BHM-7 × 90 kg P ha^{-1}	190.9 a	96.3 a	18.80 b	16.17 a
F-test	*	*	*	*
CV (%)	4.89	8.72	7.40	5.72

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; * indicates significance at 5% level of probability; BHM = BARI Hybrid Maize.

The interaction between variety and phosphorus rate brought significant variation on ear length in hybrid maize (Table 4.2). The highest ear length (96.3 cm) was recorded in the treatment combination of BARI hybrid maize-7 with 90 kg P ha^{-1} and the lowest (64.4 cm) was recorded in the treatment combination of BARI hybrid maize-3 with 0 kg P ha^{-1}.

4.1.3 Cob length

The effect of phosphorus level on cob length in hybrid maize was significant (Table 4.1). Results revealed that cob length increased with increasing phosphorus level till 60 kg P ha^{-1} and then declined with subsequent higher dose. The maximum cob length (20.8 cm) was recorded in 60 kg P ha^{-1} followed by 90 kg P ha^{-1} (20.05 cm) with same statistical rank. The minimum cob length (17.05 cm) was recorded in control plant where no phosphorus was applied. Again, cob length was positively correlated with grain yield (r = 0.99 **) (Fig. 4.1). Babu and Seshaiah (2006) observed that application of phosphorous fertilizer increased panicle length of maize that supported the present experimental result.

Varietal effect on cob length was significant (Table 4.1). The highest cob length (20.1 cm) was observed in BARI hybrid maize-2 and the lowest cob length (18.04 cm) was recorded in BARI hybrid maize-3. Genotypic variation in cob length was also observed by BARI (2009).

The interaction effect of variety and phosphorus on cob length of hybrid maize was statistically significant (Table 4.2). The highest cob length (22.23 cm) was recorded in the treatment combination of BARI hybrid maize-2 with 90 kg P ha^{-1} and the lowest

(16.93 cm) was recorded in the treatment combination of BARI hybrid maize-2 with 0 kg P ha^{-1}.

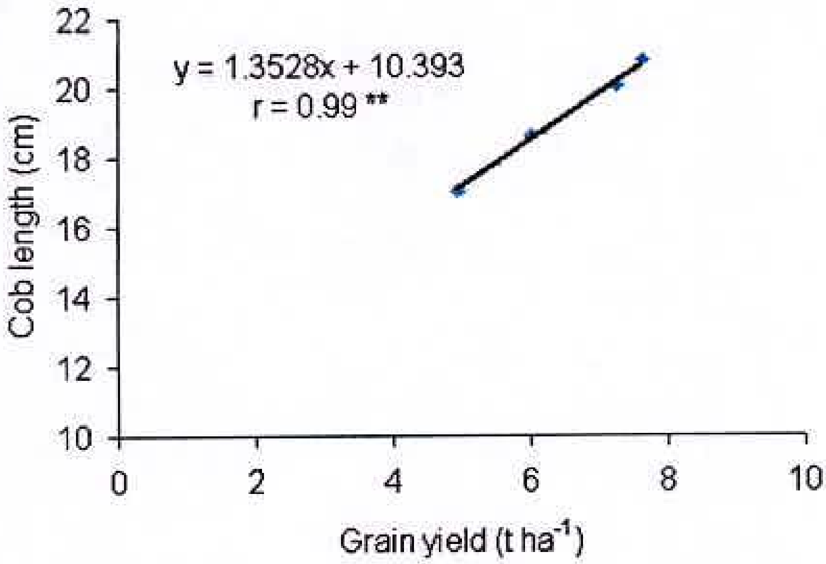

Fig. 4.1. Relationship between grain yield and cob length of hybrid maize

4.1.4 Cob circumference

Phosphorus level had significant influence on cob circumference in hybrid maize irrespective of varieties (Table 4.1). Result revealed that cob circumference was greater in phosphorus treated plant than control. But within the P levels there had no significant variation on cob circumference. The highest cob circumference (15.91 cm) was observed in 60 kg P ha^{-1} which was statistically similar to those recorded in 30 kg P ha^{-1} and 90 kg P ha^{-1}. The lowest cob circumference (14.4 cm) was recorded in control plant. Reduction in cob circumference at low phosphorous rate might be due to unavailable assimilate translocation to the cob. Similar result was also reported by many workers (Dongarwar *et* *al.*, 2003; Hussaini *et al.*, 2005; Gupta, 2007; Eva, 2008). They observed that cob circumference of maize increased in P treated plants than control.

The cob circumference varied significantly due to variety in hybrid maize (Table 4.1). The highest cob circumference was observed in BARI hybrid maize-7 (15.78 cm) followed by BARI hybrid maize-5 (15.75 cm) with same statistical rank. The lowest cob circumference was recorded in BARI hybrid maize-3 (14.66 cm). Genotypic variation in cob circumference was also observed by Begum (2008) in hybrid maize that supported the present experimental result.

The interaction between phosphorus rate and variety had significant effect on cob circumference in hybrid maize (Table 4.2). The highest cob circumference (16.40 cm) was recorded in the treatment combination of BARI hybrid maize-5 with 90 kg P ha^{-1} and the lowest (14.03 cm) was recorded in the treatment combination of BARI hybrid maize-3 with 0 kg P ha^{-1}.

4.2 Effect of phosphorus rate, variety and their interaction on yield attributes in hybrid maize

4.2.1 Number of cobs plant^{-1}

The effect of phosphorus on the number of cobs plant^{-1} was significant and ranged from 0.96 to 1.35 (Table 4.3). Results revealed that the number of cobs plant^{-1} increased with increasing phosphorus level. The highest number of cobs plant $^{-1}$ (1.35) was observed at 90 kg P ha^{-1} followed by 60 kg P ha^{-1} (1.27). In contrast, the control plot (P_0) produced the lowest number of cobs plant $^{-1}$ (0.96).

Table 4.3. Main effect of phosphorus level and variety on yield attributes in hybrid maize

Treatments	Number of cobs plant^{-1}	Weight cob^{-1} (g)	Number of grains cob^{-1}	100-grain weight
Phosphorus level (kg ha^{-1})				
0	0.96 d	132.0 c	277.3 d	33.41 c
30	1.08 c	153.5 b	432.5 c	36.68 b
60	1.27 b	198.9 a	488.5 a	38.86 a
90	1.35 a	192.2 a	464.8 a	38.73 a
F-test	**	**	**	**
Variety				
BARI hybrid maize-2	1.12 c	165.8 c	430.8 b	36.55
BARI hybrid maize-3	1.08 c	149.9 d	350.8 c	37.18
BARI hybrid maize-5	1.17 b	172.2 b	422.0 b	36.88
BARI hybrid maize-7	1.28 a	192.9 a	459.5 a	36.30
F-test	**	**	**	NS
CV (%)	3.45	6.13	5.16	4.55

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT ** indicates significance at 1% level of probability, respectively; NS = Not significant.

The lesser amount of P application may not make it much available for uptake by the plants in control plots and probably the P content was not significant for normal plant growth and development and resulted in reduction of number of cobs plant^{-1}. This result is in full agreement with that of BARI (2009) which stated that the number of cobs plant^{-1} increased with increasing phosphorous levels from 30 to 90 kg ha^{-1} in hybrid maize.

There was a significant variation in cob number plant^{-1} among the varieties in maize (Table 4.3). The highest number of cobs plant^{-1} was recorded in BARI hybrid maize-7 (1.28) followed by BARI hybrid maize-5 (1.17). The lowest number of cobs plant^{-1} was recorded in BARI hybrid maize-3 (1.08) that was statistically similar to BARI hybrid maize-2 (1.12). Genotypic variations in cobs plant^{-1} was observed by Ali *et al.* (1986) in maize that supported the present experimental result.

The interaction effect of variety and phosphorus on cobs plant^{-1} was also significant at $P \leq 0.05$ (Table 4.4). The highest number of cobs plant^{-1} (1.43) was observed in the treatment combination of BARI hybrid maize-7 with 90 kg P ha^{-1}, which was statistically similar to BARI hybrid maize-7 with 60 kg P ha^{-1} (1.40).

4.2.2 Single cob weight

Different levels of phosphorus application had significant influence on single cob weight in hybrid maize (Table 4.3). Results revealed that single cob weight was greater in phosphorus applied plots than control plots indicating application of phosphorus had effect on single cob weight. However, result revealed that single pod weight increased with increasing phosphorus level till 60 kg P ha^{-1} followed by a slight decline in the 90 kg P ha^{-1} treatment. The maximum single cob weight was recorded in 60 kg P ha^{-1} (198.9 g) followed by 90 kg P ha^{-1} (192.2 g) treatment. The minimum single pod weight (132.0 g) was recorded in control plant. Babu and Seshaiah (2006) observed that application of phosphorous fertilizer increased cob size of maize that supported the present result.

Table 4.4. Interaction effect of variety and phosphorus level on morphological characters in hybrid maize

Interaction of variety and P rate (kg ha^{-1})	Number of cobs $plant^{-1}$	Weight cob^{-1} (g)	Number of grains cob^{-1}	100-grain weight
BHM-2 × 0 kg P ha^{-1}	0.90 g	131.1 h	246.3 g	33.50 e
BHM-2 × 30 kg P ha^{-1}	1.00 ef	142.2 gh	479.0 bc	37.20 bc
BHM-2 × 60 kg P ha^{-1}	1.27 b	188.1 cd	510.3 ab	38.03 ab
BHM-2 × 90 kg P ha^{-1}	1.30 b	189.6 cd	488.7 ab	37.47 bc
BHM-3 × 0 kg P ha^{-1}	0.93 fg	113.3 i	227.3 g	33.47 e
BHM-3 × 30 kg P ha^{-1}	1.00 e	134.8 h	354.7 f	37.70 bc
BHM-3 × 60 kg P ha^{-1}	1.15 cd	171.9 def	422.7 de	40.23 a
BHM-3 × 90 kg P ha^{-1}	1.27 b	177.8 def	398.3 ef	39.33 ab
BHM-5 × 0 kg P ha^{-1}	0.93 fg	138.5 h	368.0 g	34.13 e
BHM-5 × 30 kg P ha^{-1}	1.03 e	160.0 fg	459.0 bcd	35.67 d
BHM-5 × 60 kg P ha^{-1}	1.30 b	203.7 bc	486.3 abc	39.13 ab
BHM-5 × 90 kg P ha^{-1}	1.40 a	186.6 cd	474.7 bc	38.57 ab
BHM-7 × 0 kg P ha^{-1}	1.07 e	145.2 gf	368.3 f	33.53 e
BHM-7 × 30 kg P ha^{-1}	1.20 cd	177.1 def	437.3 cde	36.17 d
BHM-7 × 60 kg P ha^{-1}	1.40 a	231.9 a	534.7 a	38.03 ab
BHM-7 × 90 kg P ha^{-1}	1.43 a	217.1 ab	498.0 a	39.57 ab
F-test	*	*	**	*
CV (%)	3.45	6.13	5.16	4.55

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; * and ** indicate significance at 5% and 1% level of probability, respectively; BHM = BARI hybrid maize

Single cob weight showed significant differences among the studied varieties (Table 4.3). BARI hybrid maize-3 produced the lowest single cob weight (149.9 g). On the other hand, BARI hybrid maize-7 produced the highest single cob weight (192.9 g).

Genotypic variations in single cob weight was also observed by Dongarwar *et al.* (2003) in maize which also supported the present experimental result.

Single cob weight was significantly influenced due to interaction effect of variety and phosphorus for maize (Table 4.4). The highest single cob weight (231.9 g) was recorded in the treatment combination of BARI hybrid maize-7 with 60 kg P ha^{-1} and the lowest (113.3 g) was recorded in the treatment combination of BARI hybrid maize-3 with 0 kg P ha^{-1}.

4.2.3 Number of grains cob^{-1}

Phosphorus fertilization had significant effect on the number of grains cob^{-1} in hybrid maize (Table 4.3). Result revealed that grains cob^{-1} increased with increasing phosphorus level till 60 kg P ha^{-1} followed by a decline. The highest number of grains cob^{-1} (488.5) was observed in 60 kg P ha^{-1} followed by 90 kg P ha^{-1} (464.8) with same statistical rank. In contrast, the lowest number of grains cob^{-1} (277.3) was recorded in control plant that was significantly different than the other treatments. Reduced number of filled grains cob^{-1} under no phosphorus application might be due to less P uptake by the plant and resulted in insufficiency of enough assimilates to fill the grains. These results are in conformity with those of Hussaini *et al.* (2005) and Khan *et al.* (2005) who reported that zero or lesser amount of P application had the lowest number of filled grains cob^{-1} compared to higher doses in maize.

Variety had significant effect on the number of grains cob^{-1} (Table 4.3). The highest number of grains cob $^{-1}$ (459.5) was recorded in BARI hybrid maize-7. The lowest number of grains cob^{-1} (350.8) was recorded in BARI hybrid maize-3. Genotypic variations in grains cob^{-1} (350.8) was also observed by Kumleh and Kavassi (2004) in maize.

The interaction effect of variety and phosphorus level on number of grains per cob was significant (Table 4.4). The highest number of grains cob^{-1} was recorded in the treatment combination of BARI hybrid maize-7 with 60 kg P ha^{-1} (534.7) followed by BARI hybrid maize-7 with 90 kg P ha^{-1} (498.0) with same statistical rank. The lowest number of grains cob^{-1} was recorded in BARI hybrid maize-3 with 0 kg P ha^{-1} treatment combination.

4.2.4 Hundred-grain weight

The effect of different levels of phosphorus on 100-grain weight was statistically significant at $P \leq 0.05$ (Table 4.3). Result revealed that 100-grain weight increased with increasing phosphorus levels till 60 kg P ha^{-1} followed by 60 kg P ha^{-1} treatment with a little decrease. The highest 100-grain weight (38.86 g) was observed in 60 kg P ha^{-1} which (38.73 g) was statistically similar to the P rate of 90 kg ha^{-1}. In contrast, the lowest 100-grain weight (33.41 g) was recorded in control plant (0 kg P ha^{-1}). Reduction in 100-grain weight at low phosphorous rate might be due to unavailable assimilate translocated to the grains. Similar result was also reported by many workers (Talukder *et al.* 1983; Thanki *et al.* 1988; Syed *et al.*, 2002; Ummed *et al.*, 2003; Zaman, 2008). They observed that 100-grain weight decreased under low phosphorus levels in maize.

Variety had no significant variation in case of 100-grain weight (Table 4.3). However, numerically the highest 100-grain weight was observed in BARI hybrid maize-

3 (37.18 g) and the lowest 100-grain weight was observed in BARI hybrid maize-7 (36.30 g). Genotypic variations in 100-seed weight of hybrid maize were also observed by Sharar *et al.* (2003) in maize.

The interaction effect of variety and phosphorus level on 100-grain weight was statistically significant at $P \leq 0.05$ (Table 4.4). The highest 100-grain weight (40.23 g) was recorded in BARI hybrid maize-3 with 60 kg P ha^{-1}. The lowest 100-grain weight was recorded in BARI hybrid maize-7 with 0 kg P ha^{-1} (33.47 g).

4.3 Effect of phosphorus rate, variety and their interaction on grain and straw yield in hybrid maize

4.3.1 Grain yield

Grain yield was significantly influenced by different levels of phosphorus application (Table 4.5). Result showed that grain yield was greater in phosphorus applied plot than in control plot where no phosphorus was applied indicating that application of phosphorus had positive effect on grain yield (Table 4.5). Result revealed that grain yield significantly increased with the increasing amount of phosphorus application up to 60 kg P ha^{-1} and then declined. The highest grain yield (7.62 t ha^{-1}) was found with 60 kg P ha^{-1}, which was statistically identical to 90 kg P $ha^{-1}$and both the treatments produced significantly higher results over 30 kg P ha^{-1} treatment. The grain yield was higher in 60 and 90 kg P ha^{-1} because of production of higher number of cobs $plant^{-1}$ and grains cob^{-1} compared to other treatments (Table 4.4). On the contrary, control plot (P_0) produced the lowest grain yield (4.94 t ha^{-1}) due to production of lesser cobs $plant^{-1}$ and grains cob^{-1}. Application of 60 kg P ha^{-1} contributed 54.2% increase yield over control, while 90 kg

ha^{-1} brought 50.8% yield benefit. The lower dose of P (30 kg ha^{-1}) gave only 21.7 % increased yield over control. Grain yield variations in maize due to phosphorus application was also observed by many researchers (Maqsood *et al.*, 2001; Ali *et al.*, 2002; Hussaini *et al.*, 2005; Babu and Seshaiah, 2006; Begum, 2008; BARI, 2009; Haider, 2009; Amanullah *et al.*, 2010).

Table 4.5. Main effect of phosphorus level and variety on grain and straw yield in hybrid maize

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Percent yield increased over control
Phosphorus level (kg ha^{-1})			
0	4.94 c	5.35 c	---
30	6.01 b	7.93 b	21.7
60	7.62 a	9.23 a	54.2
90	7.45 a	9.38 a	50.8
F-test	**	**	
Variety			
BARI hybrid maize-2	6.55 ab	7.81 b	---
BARI hybrid maize-3	6.04 b	6.91 c	---
BARI hybrid maize-5	6.44 ab	8.36 ab	---
BARI hybrid maize-7	6.81 a	8.71 a	---
F-test	*	**	
CV (%)	12.30	11.56	

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; * and ** indicate significance at 5% and 1% level of probability, respectively; NS = Not significant.

Variety had significant effect on grain yield (Table 4.5). The highest grain yield (6.81 t ha^{-1}) was recorded in BARI hybrid maize-7 followed by BARI hybrid maize-2 (6.55 t ha^{-1}) and BARI hybrid maize-5 (6.44 t ha^{-1}). The grain yield was higher in those three varieties because of production of higher number of grains cob^{-1} (Table 4.3). In contrast, the lowest grain yield was recorded in BARI hybrid maize-3 (6.04 t ha^{-1}) due to production of lowest number of cobs $plant^{-1}$ as well as lowest number of grains cob^{-1} (Table 4.3). Genotypic variations in grain yield was also observed by many workers (Thanki *et al.*, 1988; Sharar *et al.*, 2003; BARI, 2007; Moro *et al.*, 2008; Rahman, 2009).

The interaction effect of variety and phosphorus level on grain yield in hybrid maize was significant at $P \leq 0.05$ (Table 4.6). Results revealed that application of phosphorus had the highest influence on BARI hybrid maize-7 followed by BARI hybrid maize-5. Phosphorus had less influence on grain yield in BARI hybrid maize-2, in which grain yield increased up to 46.6% only over control. Results further revealed that the highest grain yield was obtained in 60 kg P ha^{-1} in all four varieties. These results indicated that 60 kg P ha^{-1} is the optimum P fertilizer dose for BARI hybrid maize-2, BARI hybrid maize-3, BARI hybrid maize-5 and BARI hybrid maize-7 grown in the AEZ-28 for getting maximum seed yield in those four varieties.

A quadratic relationship was observed between hybrid maize yield and added phosphorus (Fig. 4.2). The responses of maize grain yield to P application were very distinct. The optimum dose of phosphorus 73, 86, 70 and 78 kg P ha^{-1} was calculated from the regression equation in BARI hybrid maize-2, 3, 5 and 7 variety, respectively (Table 4.7). Using the said optimum dose, the maximum yield (7165, 6939, 7200 and 7788 kg per ha) could be expected for BHM-2, 3, 5 and 7, respectively. The economic dose (69, 81, 67 and 75 kg P ha^{-1} for BARI hybrid maize-2, 3, 5 and 7, respectively) of phosphorus was calculated from the regression equation (Table 4.7).

Table 4.6. Interaction effect of variety and phosphorus level on morphological characters in hybrid maize

Interaction of variety and P rate (kg ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Percent yield increased over control
BHM-2 × 0 kg P ha^{-1}	5.15 cd	5.50 d	---
BHM-2 × 30 kg P ha^{-1}	6.19 c	8.00 c	20.2
BHM-2 × 60 kg P ha^{-1}	7.55 ab	8.86 abc	46.6
BHM-2 × 90 kg P ha^{-1}	7.32 ab	8.88 abc	42.1
BHM-3 × 0 kg P ha^{-1}	4.64 d	5.36 d	---
BHM-3 × 30 kg P ha^{-1}	5.64 c	7.13 c	21.6
BHM-3 × 60 kg P ha^{-1}	7.04 ab	7.53 c	51.7
BHM-3 × 90 kg P ha^{-1}	6.92 ab	7.63 c	49.1
BHM-5 × 0 kg P ha^{-1}	4.88 c	5.05 d	---
BHM-5 × 30 kg P ha^{-1}	5.94 c	8.03 c	21.7
BHM-5 × 60 kg P ha^{-1}	7.66 ab	10.16 ab	56.9
BHM-5 × 90 kg P ha^{-1}	7.28 ab	10.21 ab	49.2
BHM-7 × 0 kg P ha^{-1}	4.91 cd	5.50 d	---
BHM-7 × 30 kg P ha^{-1}	6.26 c	8.56 bc	27.5
BHM-7 × 60 kg P ha^{-1}	8.13 a	10.38 a	65.6
BHM-7 × 90 kg P ha^{-1}	7.97 a	10.58 a	62.3
F-test	*	*	
CV (%)	12.3	11.56	

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; * and ** indicate significance at 5% and 1% level of probability, respectively; BHM = BARI hybrid maize

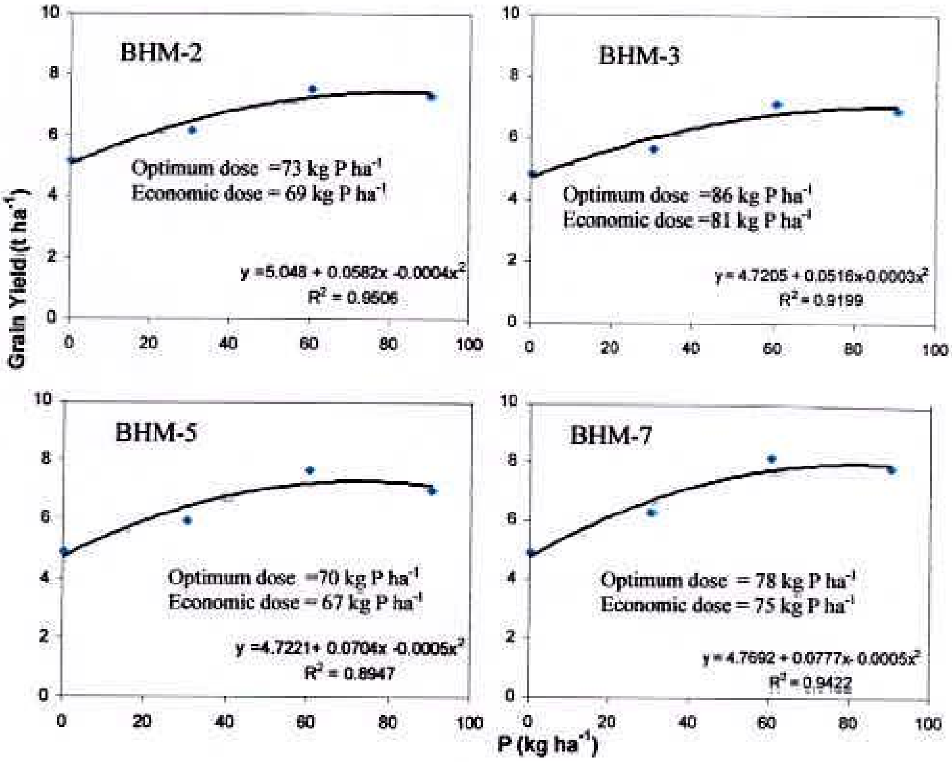

Fig. 4.2. Response of different varieties of hybrid maize to phosphorus fertilization at Joydebpur during 2008-2009.

Table 4.7. Response function of hybrid maize to phosphorus at Joydebpur during 2008-2009

Regression equation	Coefficient of determination	Optimum dose	Economic dose	Maximum yield from optimum dose	Production of maize grain for 1 kg P (use efficiency)
				(kg ha^{-1})	
BARI hybrid maize-2					
$y=5.048+0.0582x-0.0004x^2$	0.95	73	69	7165	29
BARI hybrid maize-3					
$y= 4.7205+0.0516x-0.0003x^2$	0.92	86	81	6939	26
BARI hybrid maize-5					
$y= 4.722+0.0704x-0.0005x^2$	0.90	70	67	7200	35
BARI hybrid maize-7					
$y= 4.7692+0.0777x-0.0005x^2$	0.94	78	75	7788	39

P= Phosphorus

4.3.2 Straw yield

Different levels of phosphorus application on hybrid maize had significant effect on straw yield (Table 4.5). Results revealed that straw yield increased with increasing phosphorus levels up to 90 kg P ha^{-1}. The highest straw yield (9.38 t ha^{-1}) was recorded in 90 kg P ha^{-1} followed by 60 kg P ha^{-1} (9.23 t ha^{-1}) with same statistical rank. On the contrary, P_0 produced the lowest straw yield (5.35 t ha^{-1}) due to lesser growth and development of plants (Table 4.1). Eva (2008) observed that increasing levels of P also increased the dry matter yield significantly up to 175% RFD of P that also supported the present investigation.

There was significant variation in straw yield among the varieties of hybrid maize (Table 4.5). The highest straw yield (8.71 t ha^{-1}) was recorded in BARI hybrid maize-7 followed by BARI hybrid maize-5 (8.36 t ha^{-1}) with same statistical rank. In contrast, the lowest straw yield was recorded in BARI hybrid maize-3 (6.91 t ha^{-1}) due to shorter plant (Table 4.1). A genotypic variation in straw yield was also observed by many workers (Thanki *et al.*, 1988; Sharar *et al.*, 2003; BARI, 2007; Moro *et al.*, 2008; Rahman, 2009).

The interaction effect of variety and phosphorus level on straw yield in hybrid maize was significant at $P \leq 0.05$ (Table 4.6). The highest straw yield was recorded in the treatment combination of BARI hybrid maize-7 with 90 kg P ha^{-1} (10.58 t ha^{-1}) followed by BARI hybrid maize-7 with 60 kg P ha^{-1} (10.38 t ha^{-1}). The lowest straw yield (5.05t ha^{-1}) was recorded in BARI hybrid maize-5 with 0 kg P ha^{-1}.

4.4 Uptake and apparent P balance

In general, the grain yield of maize increased with increased P uptake and it was consistent up to the 60 kg P ha^{-1} application (Table 4.5). The highest total P uptake (44 kg ha^{-1}) was obtained by BARI hybrid maize-5 with the highest rate of P application (90 kg P ha^{-1}) (Table 4.8). Phosphorus uptake by maize plant was the lowest at P controlled treatment. However, in all the varieties of hybrid maize, P uptake was increased with increasing rate of P application. This observation was in agreement with the findings of Venkatesh *et al.* (2002) and Tchienkoua *et al.* (2008). The apparent P balance is presented in Table 4.8. Phosphorus showed a positive balance at all the treatments except the P omitted treatments. Phosphorus showed positive balance ranging from 6 to 80 in BARI hybrid maize-2, 6 to 75 in BARI hybrid maize-3, 6 to 72 in BARI hybrid maize-5 and 5 to 74 kg P ha^{-1} in BARI hybrid maize-7.

4.5 Cost and return

The cost and return analysis showed that highest gross margin (TK. 62118 ha^{-1} yr^{-1}) was obtained from the treatment T_{15} where the fertilizer dose was 60 kg P ha^{-1} with variety BARI hybrid maize-7 (Table 4.9). This is followed by T_{11} (TK 58580 ha^{-1} yr^{-1}) with BARI hybrid maize-5. The gross margin in BARI hybrid maize-2 and BARI hybrid maize-3 was the highest with 60 kg P ha^{-1} (Table 7.9). The MBCR of these treatments are also high. The MBCR of T_{15}, T_{11}, T_7 and T_3 are 1.6, 1.5, 1.1 and 0.8, respectively. Considering the economic returns, 60 kg P ha^{-1} for maize cultivation may be considered as economically profitable.

Table 4.8. Phosphorus uptake and apparent P balance as affected by different levels of P in different hybrid maize

Treatment	P added (kg/ha)	Total P harvest (kg/ha)	Apparent P balance (kg/ha)
BHM-2 × 0 kg P ha^{-1}	0 (26)	20	6
BHM-2 × 30 kg P ha^{-1}	30 (26)	28	28
BHM-2 × 60 kg P ha^{-1}	60 (26)	36	50
BHM-2 × 90 kg P ha^{-1}	90 (26)	36	80
BHM-3 × 0 kg P ha^{-1}	0 (26)	20	6
BHM-3 × 30 kg P ha^{-1}	30 (26)	30	26
BHM-3 × 60 kg P ha^{-1}	60 (26)	38	48
BHM-3 × 90 kg P ha^{-1}	90 (26)	41	75
BHM-5 × 0 kg P ha^{-1}	0 (26)	20	6
BHM-5 × 30 kg P ha^{-1}	30 (26)	31	25
BHM-5 × 60 kg P ha^{-1}	60 (26)	43	43
BHM-5 × 90 kg P ha^{-1}	90 (26)	44	72
BHM-7 × 0 kg P ha^{-1}	0 (26)	21	5
BHM-7 × 30 kg P ha^{-1}	30 (26)	32	24
BHM-7 × 60 kg P ha^{-1}	60 (26)	41	45
BHM-7 × 90 kg P ha^{-1}	90 (26)	42	74

Figures in parenthesis indicate P derived from cowdung. Mineralization rate of P for cowdung is about 40%.

Table 4.9. Cost and return analysis of hybrid maize as affected by phosphorus fertilization

Treatment	Grain Yield (kg ha^{-1})	Gross return (Tk. ha^{-1} yr^{-1})	Variable cost (Tk. ha^{-1} yr^{-1})	Gross margin (Tk. ha^{-1} yr^{-1})	MBCR
T_1 (BHM-2 × 0 kg P ha^{-1})	4717	47169	16375	30794	-
T_2 (BHM-2 × 30 kg P ha^{-1})	5944	59438	18475	40963	0.4
T_3 (BHM-2 × 60 kg P ha^{-1})	6826	68260	20575	47685	0.8
T_4 (BHM-2 × 90 kg P ha^{-1})	6671	66715	22675	44040	0.7
T_5 (BHM-3 × 0 kg P ha^{-1})	4620	46198	16375	29823	-
T_6 (BHM-3 × 30 kg P ha^{-1})	6026	60260	18475	41785	0.6
T_7 (BHM-3 × 60 kg P ha^{-1})	7120	71198	20575	50623	1.1
T_8 (BHM-3 × 90 kg P ha^{-1})	7005	70054	22675	47379	1.0
T_9 (BHM-5 × 0 kg P ha^{-1})	4458	44577	16388	28189	-
T_{10} (BHM-5 × 30 kg P ha^{-1})	6179	61788	18475	43313	0.7
T_{11} (BHM-5 × 60 kg P ha^{-1})	7916	79155	20575	58580	1.5
T_{12} (BHM-5 × 90 kg P ha^{-1})	7556	75555	22675	52880	1.2
T_{13} (BHM-7 × 0 kg P ha^{-1})	4654	46535	16375	30160	-
T_{14} (BHM-7 × 30 kg P ha^{-1})	6554	65536	18475	47061	0.9
T_{15} (BHM-7 × 60 kg P ha^{-1})	8269	82693	20575	62118	1.6
T_{16} (BHM-7 × 90 kg P ha^{-1})	8032	80323	22675	57648	1.4

Input price

Urea = Tk. 6.00/kg
TSP = Tk. 14.00/kg
MP = Tk. 12.50/kg
Gypsum = Tk. 3.00/kg
Zinc sulphate = Tk. 60.00/kg
Magnesium sulphate = Tk. 40.00/kg
Boric acid = Tk. 100.00/kg
CD = Tk. 0.75/kg
* Variable cost includes fertilizer cost only

Output Price:
Maize grain = Tk.10.00/kg

CHAPTER V

SUMMARY AND CONCLUSION

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A field experiment was conducted at the Central Research Farm of Bangladesh Agricultural Research Institute, Gazipur during the period from November 2008 to April 2009 to investigate the effect of different levels of phosphorus application on growth, yield attributes and yield of hybrid maize. The soil belongs to the Chhiata soil series under the AEZ-28 (Madhupur Tract). Characteristically, the soil is clay loam having pH 6.20, organic matter 1.7%, total nitrogen 0.052%, available phosphorus 13.1 ppm, exchangeable potassium 0.39 me/100 g soil and available sulphur 8.51 ppm. The experiment comprised four hybrid maize varieties *viz.*, BARI hybrid maize-2, BARI hybrid maize-3, BARI hybrid maize-5 and BARI hybrid maize-7 and four levels of phosphorus application *viz.* 0, 30, 60 and 90 kg ha^{-1}. Phosphorus was applied from TSP to the experimental plot during final land preparation as per treatments. The experiment was laid out in two factors randomized complete block design with three replications. The collected data were analyzed statistically and the means were separated by DMRT at 5% level of probability.

The effect of phosphorus levels on morphological characters (plant height, ear height, cob length and cob circumference), yield contributing characters (cobs $plant^{-1}$, weight cob^{-1}, grains cob^{-1} and 100-grain weight) and, grain and straw yield was significant. Results revealed that morphological and yield contributing characters were greater in phosphorus treated plants than control plants. Results showed that plant height and ear length increased with increasing P levels till 90 kg P ha^{-1}, whereas cob length and cob circumference increased upto 60 kg P ha^{-1} treatment and then declined. The highest plant and ear height were recorded in 90 kg P ha^{-1} followed by 60 kg P ha^{-1} treatment. In contrast, the shortest plant and ear height were recorded in control plant, where no phosphorus was applied. The highest cob length and cob circumference were observed in 60 kg P ha^{-1} followed by 90 kg P ha^{-1} treatment. The lowest cob length and cob circumference were observed in control plant. In case of yield attributes, results showed that single cob weight, number of grains cob^{-1} and 100-grain weight increased with increasing phosphorus level upto 60 kg ha^{-1} followed by an insignificant decline with higher dose of P, whereas cob number $plant^{-1}$ increased till 90 kg P ha^{-1} treatment. The highest single cob weight, grains cob^{-1} and 100-grain weight were recorded in 60 kg P ha^{-1} where as the highest number of cobs $plant^{-1}$ was recorded in 90 kg P ha^{-1}. The lowest number of cobs $plant^{-1}$, single cob weight, number of grains cob^{-1} and 100-grain weight were recorded in control. The grain yield increased with increasing phosphorus level followed by a decline with higher P dose, whereas straw yield increased with increasing phosphorus level till 90 kg ha^{-1}. These results indicated that dry matter partitioning to economic yield was better with 60 kg P ha^{-1} than 90 kg P ha^{-1} in maize. The highest grain yield was recorded in 60 kg P ha^{-1} (7.62 t ha^{-1}) followed by 90 kg P ha^{-1} (7.45 t ha^{-1}) with same statistical rank. These results indicate that 90 kg P ha^{-1} is luxurious for cultivating of hybrid maize varieties under AEZ-28. The grain yield was higher in 60 and 90 kg P ha^{-1} might be due to increased number of cobs $plant^{-1}$, number of grains cob^{-1} and 100-grain weight. The highest straw yield was recorded in 90 kg P ha^{-1} (9.38 t ha^{-1}) which was identical to 60 kg P ha^{-1} (9.23 t ha^{-1}). The grain yield was increased by 54.2, 50.8 and 28.7% over P control for 60, 90 and 30 kg ha^{-1}, respectively.

The response of maize to P application was very distinct. The optimum dose of phosphorus 73, 86, 70 and 78 kg P ha^{-1} was calculated from the regression equation for BARI hybrid maize-2, 3, 5 and 7, respectively. The economic dose of phosphorous (69, 81, 67 and 75 kg P ha^{-1} for BARI hybrid maize-2, 3, 5 and 7, respectively) was calculated from the regression equation.

Phosphorus levels significantly influenced phosphorus content and uptake in grain and straw. Result revealed that total phosphorus harvest increased with increasing phosphorus levels. Phosphorus showed a positive balance at all the treatments except the P omitted treatments. Phosphorus showed positive balance ranging from 6 to 80 in BARI hybrid maize-2, 6 to 75 in BARI hybrid maize-3, 6 to 72 in BARI hybrid maize-5 and 5 to 74 kg P ha^{-1} in BARI hybrid maize-7. However, the grain yield performance was greater in 60 kg P ha^{-1} than that of 90 kg P ha^{-1}, but the total uptake of phosphorus by maize plant was greater in 90 kg P ha^{-1} than in 60 kg P ha^{-1}. This result indicated that application of phosphorus at the rate of 90 kg ha^{-1} is excessive for maximizing the grain yield of hybrid maize to be cultivated under AEZ-28.

The dose 60 kg P ha^{-1} appeared as the economically profitable providing with higher MBCR irrespective of varieties in case of all the tested varieties.

The effect of variety on morphological, yield attributes and yield was significant. Results revealed that the variety BARI hybrid maize-7 was superior in morphological and yield attributes resulting the highest yield potentiality.

It may be concluded that growth and yield of hybrid maize were highly influenced by different levels of phosphorus application. From response function, the optimum dose of phosphorus was found to be 73, 86, 70 and 78 kg ha^{-1} for BHM-2, BHM-3, BHM-5 and BHM-7, respectively for maximizing the yield of maize. Among the phosphorus fertilizer treatments, 60 kg P ha^{-1} application along with a blanket dose of $N_{250}K_{100}S_{40}Mg_{10}Zn_5B_2$ kg ha^{-1} and cowdung 5 t ha^{-1} appeared to be the best suited dose for optimizing grain yield of hybrid maize with the maximum economic profit in the AEZ-28 of Bangladesh.

Therefore, the said P dose along with a balance dose 73, 86, 70 and 78 kg ha^{-1} for BHM-2, BHM-3, BHM-5 and BHM-7 may be recommended for the respective varieties for the cultivation of hybrid maize.

CHAPTER VI
REFERENCES

REFERENCES

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APPENDICES

APPENDICES

Appendix I. Analysis of variance (mean square) on morphological characters of hybrid maize

Source of variation	df	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob circumference (cm)
Replication	2	2.41	415.6	40.42	1.02
Variety (A)	3	752.2 **	578.3 **	7.15 *	3.47 **
Phosphorus level (B)	3	1692.5 **	966.5 **	29.53 **	3.12 *
A × B	9	194.62 *	144.2 *	4.28 *	1.664 *
Error	30	64.75	50.69	1.97	0.768

* and ** indicate significant at 5% and 1% level of probability, respectively

Appendix II. Analysis of variance (mean square) on yield attributes of hybrid maize

Source of variation	df	Number of cobs $plant^{-1}$	Weight cob^{-1} (g)	Number of grains cob^{-1}	1000-grain weight
Replication	2	0.002	10.026	910.27	30.72
Variety (A)	3	0.079 **	3951.7 **	20838.9 **	20.70 ns
Phosphorus level (B)	3	0.381 **	10377.7 *	101340.1 **	66.23 **
A × B	9	0.004 *	235.36 *	3322.47 **	4.83 *
Error	30	0.002	103.83	447.80	2.78

* and * indicate significant at 5% and 1% level of probability, respectively

Appendix III. Analysis of variance (mean square) on grain and straw yield of hybrid maize

Source of variation	df	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
Replication	2	0.028	0.11
Variety (A)	3	2.855 *	5.25 **
Phosphorus level (B)	3	17.89 **	22.21 **
A × B	9	1.625 *	1.86 *
Error	30	0.853	0.552

* and ** indicate significant at 5% and 1% level of probability, respectively