GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY PHOSPHORUS AND POTASSIUM

NAFISA JALAL

DEPARTMENT OF HORTICULTURE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY PHOSPHORUS AND POTASSIUM

By

NAFISA JALAL

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Approved by

Prof. Md. Hasanuzzaman Akand	**Prof. Dr. Md. Nazrul Islam**
Department of Horticulture	Department of Horticulture
SAU, Dhaka	SAU, Dhaka
Supervisor	**Co-supervisor**

Prof. Dr. A.F.M. Jamal Uddin
Chairman
Examination Committee

Department of Horticulture

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Memo No:……. Date:……..

CERTIFICATE

This is to certify that thesis entitled, "**GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY PHOSPHORUS AND POTASSIUM**" submitted to the **Faculty of Agriculture**, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE,** embodies the result of a piece of *bona fide* research work carried out by **NAFISA JALAL, Registration No. 07-02241** under my supervision and guidance. No of part of the thesis has been submitted for any other degree of 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: December, 2013
Dhaka, Bangladesh

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Prof. Md. Hasanuzzaman Akand
Department of Horticulture
SAU, Dhaka
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENT

*All praises and compliments are due to the Supreme Regulator and Ruler of the Universe, "**Almighty Allah**" for the blessing upon the successful accomplishment of education, to complete the research work and thesis leading to Master of Science (MS) in Horticulture.*

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The Author

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ABSTRACT

The experiment was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2012 to February 2013. The experiment consisted with two factors. Factor A: Three levels of Phosphorus i.e. P_0: control; P_1: 45 kg and P_2: 65 kg P_2O_5/ha and Factor B: Four levels of potassium as K_0: 0 kg (control), K_1: 125 kg, K_2: 145 kg and K_3: 165 kg K_2O/ha respectively. The experiment was laid out in a Randomized Complete Block Design with three replications. For Phosphorus, the highest plant height (26.52 cm), number of loose leaves (17.01), dry weight (7.73 g), head weight (1.84 kg) and yield (49.73 t/ha) of cabbage was produced by treatment P_1. On the other hand, for Potassium K_3 performed the highest plant height (25.01 cm), number of loose leaves (17.48), dry weight (8.50 g), head weight (1.86 kg) and yield (49.1 t/ha) of cabbage. For combined effect, P_1K_3 gave the highest yield (59.22 t/ha) and P_0K_0 gave the lowest yield (28.11 t/ha). So, 45 kg P_2O_5/ha with 165 kg K_2O/ha may be considered as an optimum dose for cabbage production.

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LIST OF ABBREVIATIONS

%	=	Percent
AEZ	=	Agro Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
cm	=	Centimetre
cv.	=	Cultivar (s)
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.	=	And Others
FAO	=	Food and Agriculture Organization of United Nations
g	=	Gram
ha^{-1}	=	per Hectare
HYV	=	High Yielding Variety
$plant^{-1}$	=	per plant
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
t/ha	=	Ton per Hectare

CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea var. capitata* L.), a member of cruciferae and a useful vegetable, belongs to the genus Brassica. Cabbage is related to turnips, cauliflowers and brussels sprout (Jim and Tony, 2006). It is generally believed to have originated from the wild, leafy, non-heading types which are found growing in Europe (Grubben and Denton, 2004). It is a biennial crop that is grown as an annual, unless it is grown for seed production (Ryder, 1979; Pierce, 1987). The transition from vegetative to reproductive growth is triggered by temperature. It is a cool season crop; therefore, it will produce flowers if grown in areas of mild winters. This unique vegetable has been widely grown in both tropical and temperate regions of the world (Sarker *et al.*, 2002).

Among the vegetable grown in Bangladesh, cabbage ranks the second in respect of production and area. The leading cabbage growing districts in Bangladesh are Kustia, Meherpur, Jessore, Bogra and Tangail (Sarker *et al*., 2002). There were 15783 hectors land under cabbage cultivation with a production of 207 thousand metric tons in the country during the year 2011-2012 (BBS, 2011). With an average yield of 13.09 t ha^{-1} which is quite low in comparison with other countries of the world like Germany (54.61 t/ha), Japan (40.32 t/ha) and India (19.12 t/ha) (FAO, 1998).

The Food and Agricultural Organization (FAO, 1988) has identified cabbage as one of the top twenty vegetables and an important source of food globally. It has been domesticated and used for human consumption since the earliest antiquity (Smith, 1995). It is a rich source of vitamin A and C. The green outer leaves of cabbage are richer in vitamin A, calcium and iron than the white inner leaves. Headed cabbage are usually consumed as a cooked vegetable, or eaten fresh as an ingredient of coleslaws and mixed salads (Grubben and Denton, 2004).

Cabbage is not rich in nutrients but based on the volume consumed, it contributes a lot to the daily nutrient requirements of an average adult (Ryder, 1979; Peirce, 1987). Cabbage is low in calories and protein content, but is a good source of many minerals, particularly potassium, and is relatively high in sulphur, calcium, vitamins A, C, B_l and B_2 (Smith, 1995; Tiwari *et al.*, 2003). Sulphur contributes to the cooking smell of cabbage (Smith, 1995). Green cabbage cultivars tend to have more vitamin A than red cultivars, and savoy types tend to have more vitamin A than smooth types. The National Science and Development Board (1980) found out that l00 g edible portion of cabbage contains 74 mg calcium, 28 mg phosphorus, 0.8 mg iron, 11 mg sodium and 212 mg potassium. According to Singh and Naik (1988), 100 g of edible portion of cabbage contains 1.8 g protein, 0.1 g fat, 4.6 g carbohydrate, 29 mg calcium, 0.8 mg iron and 14.l mg sodium.

Phosphorus (P) is essential for the general health and vigour of plants. Adequate availability of Phosphorus (P) stimulates root development, increases stalk and stem strength and improves flower formation, fruiting and seed production. It also enhances uniform and early crop maturity, increases the nitrogen fixing capacity of legumes, improves crop quality and increases resistance to plant diseases (Mitchell, 1970; Plaster, 1985, 2003; Ahmed *et al.*, 2003). Phosphorus deficiency retards plant growth (Jones, 2003). On the other hand excessive phosphate levels can depress plant growth (Mengel and Kirby, 1982). Phosphorus is toxic to plants when the Phosphorus level in tissues exceeds 1% (Jones, 2003). Phosphorus toxicity is associated with a reduction in the uptake and translocation of Zn, Fe and Cu (Jones, 2003).

Potassium (K) is essential in photosynthesis, sugar translocation, nitrogen metabolism, enzyme activation, stomatal functioning, water relations and growth of meristematic tissues (Mitchell, 1970; Follett, *et al.*, 1981). Potassium exerts balancing role on the effects of both nitrogen and phosphorus, consequently it is especially important in multi-nutrient fertilizer application (Brady, 1990). Mitchell (1970) describes Potassium as a major osmotic ion for the regulation of

water flow in the plant. Potassium is also found in the leaves, where it acts as a catalyst for reactions involved in the activation of enzymes, synthesis of proteins, synthesis and translocation of starch and translocation of NO_3^- (Archer, 1988). Plants well supplied with Potassium have strong stems that are resistant to lodging. Potassium makes plants more winter-hardy, less likely to be injured by spring or autumn frosts and it helps them to resist diseases (Mengel and Kirby, 1982). Potassium also encourages root development, but not to the same extent as P (Plaster, 2003). Excess Potassium can cause plants to first become deficient in Mg, and then in Ca, due to induced nutrient imbalances, which upset the Potassium: Mg and K: Ca ratios, especially when Mg and Ca availability are at the low end of their sufficiency ranges (Jones, 2003).

Analysis of soil samples of important soil types and series of Bangladesh reveals that 80-90% soils are poor in zinc and sulphur, while 100% soils are deficit in nitrogen (Porch and Islam, 1984). Besides this deficiency in phosphorus and potassium is now considered as one of the major constraint to successful production of upland crops (Islam and Noor, 1982). Moreover, the proportion of nutrient applied by vegetable growers in Bangladesh is not balanced. Use of imbalanced nutrients in the soils may be harmful and causing our agricultural soil degraded and unproductive (Hossain *et al.,* 2011). Thus, the nutrient deficient soils must be identified and these soils should be enriched with these nutrients through balanced use of fertilizer.

Considering the above facts, the present investigation was carried out on the following objectives

1. To find out the optimum doses of phosphorus and potassium for the better vegetative growth, maximum yield of cabbage.
2. To find out the suitable combination of Phosphorus and Potassium for the better vegetative growth and yield of cabbage.

CHAPTER II

REVIEW OF LITERATURE

Cabbage is an important vegetable crop of many countries of the world as well as in Bangladesh. It is a heavy feeder of phosphorus and potassium. Different levels of phosphorus and potassium application influence on the growth and yield of the crop. Optimum doses of phosphorus and potassium application are related to better yield of cabbage. It is important to assess the optimum doses phosphorus and potassium for the better yield of cabbage in Bangladesh. A good number experiments on the effects of phosphorus and potassium on the growth and yield of cabbage was conducted in different parts of the world. But limited numbers of studies are found in this respect in Bangladesh. However, some of the important research findings regarding the effects of phosphorus and potassium on the growth and yield of cabbage have been presented in this chapter

2.1 Effect of phosphorus on the growth and yied of cabbage.

Phosphorus is essential for the general health and vigour of plants. Adequate availability of Phosphorus stimulates root development, increases stalk and stem strength and improves flower formation, fruiting and seed production. It also enhances uniform and early crop maturity, increases the nitrogen fixing capacity of legumes, improves crop quality and increases resistance to plant diseases (Mitchell, 1970; Plaster, 1985, 2003; Ahmed *et al.*, 2003).

Phosphorus deficiency retards plant growth. Symptoms of Phosphorus deficiency typically appear in the older leaves, in the form of purplish areas and necrosis of leaf margins. The stems of many annual plants suffering from Phosphorus deficiency are characterized by a reddish colouration originating from an enhanced formation of anthocyanins. Leaves are frequently tinged with a brownish colour and drop off prematurely (Jones, 2003).

Excessive phosphate levels can depress plant growth (Mengel & Kirby, 1982). Phosphorus is toxic to plants when the Phosphorus level in tissues exceeds 1% (Jones, 2003). Phosphorus toxicity is associated with a reduction in the uptake and translocation of Zn, Fe and Cu (Jones, 2003).

In soils, phosphorus occurs in organic and inorganic forms (Jones, 2003). For plants, inorganic phosphorus in the form of the phosphate ion $H_2PO_4^-$ is the most important source of this element (Bolland & Gilkes, 1998).

Hossain *et al.* (2011) conducted an experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during October 2006 to May 2007 to study the response of cabbage to fertilizer application in Salna silty clay loam soil. The experiment was carried out to study the response of cabbage variety Autumn Queen to added N, P, K and S nutrients in respect of growth, dry matter production and yield, nutrient contents in loose and heading leaves of the crop. Treatment receiving 240 kg N, 45 P, 180 kg K and 45 S/ ha performed the best in recording plant height, root length, number of loose and heading leaves, leave length and breadth, thickness and diameter of head and yield.

Prasad *et al*. (2009) conducted an experiment on response of chinese cabbage to different doses of nitrogen and phosphorus levels. Analysis of variance showed significant differences among the treatments for all the traits. The maximum number of outer leaves, head length, head width, total head weight, net head weight and head yield were obtained with the application of 120kg N/ha and 100kg P/ha .Where as the maximum plant height, plant spread, leaf area and head diameter were recorded with the application of 140kgN/ha and 120kgP/ha. From the experiment, suggested that the application of 120kg nitrogen /ha and 100kg P/ha are best for obtaining higher production in Chinese cabbage in the Gangetic plains of West Bengal.

Bishop *et al.* (2007) conducted a experiment on fertilizer treatments for cabbage, grown on sphagnum peat, consisted of an N, a P and a K series. Each nutrient was applied at four rates in combination with constant rates of the other two. Results

indicated that 270 kg N/ha, the highest rate used, may not have been adequate whereas P and K at 80 and 150 kg/ha respectively were. In the N, the P, and the K series, highest head weights coincided with midribs containing 2.06% N, 0.48% P and 4.18% K respectively.

Warg-Zhaottui and Li-Shengkiu (2004) studied the response of cabbage or the effects of nitrogen forms and rates and phosphorus treatment or their growth and nitrate accumulation. Finally they observed nitrate concentration in vegetables (cabbage) were positively casemated with N rates. As a result, addition of N fertilizers to roil was the major cause for vegetables increasing their nitrate contents. Again with the addition of P fertilizer yield of cabbage was increased different organs had different amount of nitrate accumulation and it was found that nitrate concentrations were much higher in roots stems and petioles than in blades at any N rate.

Bojokalfa *et al.* (2003) conducted an experiment to determine the effect of phosphorus application on yield quality and mineral matter content in Savoy cabbage [B. *oleracea* cease vary Sabauda]. In the experiment 0, 4,8,8,12,16 kg P205/ha was applied. After the harvest, the number of unmarketable outer leaves, head diameter, head weight, average yells dry matter and mineral matter content were determined. Phosphorus application effected the number of unmarketable other leaves, head diameter, average head weight and yield the highest yield of 2546 kg/ha was reduced from 4 kg P_2O_5 N/ha then was decreased at this point. However, increasing fertilizer levels increased mineral matter content in the leaves.

Halim *et al.* (1994) carried out an experiment on the effect of different doses of NPK on the growth and yield of cabbage in 1990-91 at Jamalpur. Nitrogen was applied at 0, 100, 150, or 150 kg P_20_5 N/ha in combination to cabbage V. K-K cross. Gross yield and marketable head weight per plant were maximum with 150 kg N_2 + 100 g P_2O_5 N/ha 150 kg K_2O or 200 kg N_2 + 100 kg P_2O_5+ 150 kg K_2O combination.

The effect of 3 spacing, N at 60-120 kg/ha P_2O_5 + 30-90 kg/ha on the yield and its attributes of cabbage cv. Pride of India studied by Shing and Naik (1988). They reported that the closest spacing (45 cm x 30 cm) gave higher numbers of marketable heads which resulted in the highest yield. The head weight was maximum at 60 cm x 45 cm spacing. Nitrogen at the rate of 180 kg/ha was significantly increased yield and number of marketable heads. Application of Phosphorus 60 kg/ha gave the highest yield average head weight and number of head/ha.

Phosphorus occurs in seeds as phytin, which acts as a source of Phosphorus for young plants. As phospholipids, Phosphorus acts as a storage mechanism and it plays a role in the selective permeability of cell walls for ions. In the nucleic acids DNA and RNA, which are the carriers of all genetic characteristics, P acts as a coupling between molecules. Phosphorus also occurs in ADP and ATP (Mitchell, 1970).

2.2 Effect of potassium on growth and yield of cabbage.

Potassium is absorbed by plants in the form of the potassium ion (K^+). Soil Potassium exists in solution and in exchangeable and non-exchangeable forms, which are in dynamic equilibrium with each other (Cox *et al.,* 1999). Solution Potassium and exchangeable Potassium are replenished by non-exchangeable Potassium when they are depleted by plant removal or leaching (Gardiner and Miller, 2004).

Potassium is essential in photosynthesis, sugar translocation, nitrogen metabolism, enzyme activation, stomatal functioning, water relations and growth of meristematic tissues (Mitchell, 1970; Follett, *et al.,* 1981). Mitchell (1970) describes Potassium as a major osmotic ion for the regulation of water flow in the plant. Potassium is also found in the leaves, where it acts as a catalyst for reactions involved in the activation of enzymes, synthesis of proteins, synthesis and translocation of starch and translocation of NO_3^- (Archer, 1988). Plants well

supplied with Potassium have strong stems that are resistant to lodging. Potassium makes plants more winter-hardy, less likely to be injured by spring or autumn frosts and it helps them to resist diseases (Mengel and Kirby, 1982). Potassium also encourages root development, but not to the same extent as P (Plaster, 2003).

In many plants, K deficiency does not immediately result in visible hunger symptoms. At first there is only a reduction in the growth rate (hidden hunger), and only later chlorosis and necrosis may occur (Mengel & Kirby, 1982). Generally, these symptoms first occur in the older leaves, because Potassium is translocated from old to young foliage. In most plant species 16 necrosis and chlorosis first occur along the margins and tips of the leaves (Plaster, 1985, 2003)

Excess K can cause plants to first become deficient in Mg, and then in Ca, due to induced nutrient imbalances, which upset the K: Mg and K: Ca ratios, especially when Mg and Ca availability are at the low end of their sufficiency ranges (Jones, 2003). The negative response of plants to high applications of K may also be the result of an excessive salt concentration in the soil solution, which causes various types of chemical and physical stress in plants (Kuiper, 1984; Pasternak, 1987). According to Munns (1993), growth inhibition by salt stress is associated with alterations in the water relationships within the plant caused by osmotic effects.

Hossain *et al.* (2011) conducted a experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during October 2006 to May 2007 to study the response of cabbage to fertilizer application in Salna silty clay loam soil. The experiment was carried out o study the response of cabbage variety Autmn Queen to added N, P, K and S nutrients in respect of growth, dry matter production and yield, nutrient contents in loose and heading leaves of the crop. Treatment receiving 240 kg N, 45 P, 180 kg K and 45 S/ ha performed the best in recording plant height, root length, number of loose and heading leaves, leave length and breadth, thickness and diameter of head and yield.

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Halim *el al.* (1994) conducted an experiment on the effect of different doses of NPK on growth and yield of cabbage at Jamalpur in Bangladesh. Nitrogen was applied at 0, 100, 150 or 200 kg/ha, P at 0, 50, 100 or 150 kg P_2O_5 and K at 0, 75, 150 or 225kg K_2O/ha in 12 combinations to cabbage cv. K-K cross. Gross yield and marketable head weight per plant were found the highest with 150 kg N+ 100 kg P_2O_5 + 150 kg K_2O or 200 kg N + 100 kg P_2O_5 +150 kg K_2O.

Tianxiu *et al.* (1994) studied the effect of K and Mg fertilizers applied to cabbage yield, quality and economic return and found that cabbage yield was higher with 150 kg K_2O/ha than with no potassium. The best cash return was also obtained with 150 kg K_2O/ha.

Jothi *et al.* (1993) carried out an experiment on the influence of N, P and Azospirillum on the yield of cabbage at Tamil Nadu in India. They reported that a cabbage yield of 117.2 t/ha was obtained with the application of N, P and K at 100,125 and 25 kg/ha respectively.

Aditiya (1993) reported that the Rabi season cabbage (Var.Atlas-70) required 225 kg K_2O/ha for its higher production.

Samant *et al.* (1992) investigated the balanced fertilizer use for cabbage in clay loam soils of Orissa, India. It was reported that nitrogen (75kg/ha) and potassium (150 kg/ha) gave the highest yield (17.42 t/ha), and it was the most economic dose.

Rao and Subramaniun (1991) conducted an experiment to find out the effect of potassium application on the yield and content of potassium, calcium and magnesium in cabbage at Bangalore in India. They applied K_2O at 0, 25, 50, 100, 150 and 200 kg/ha. They observed that the plant K concentration at all stages of growth increased significantly at the increasing level of K_2O application

Yetistiren and Vural (1991) studied the effects of various fertilizer applications on cabbage yield and quality. Nitrogen was applied at 10 or 20 kg/ha and K at 15 or 30 kg K_20/ha. They reported that highest yield was obtained with 20 kg N + 30 kg K_2O/ha.

An experiment was carried out at Joydebpur, Gazipur on cabbage (var. Atlas-70) during Rabi season to fiendout the effects of fertilizer doses and organic manure on the yield of cabbage (Anonymous, 1991). The application of 240 kg N/ha, 60 kg P/ha and 120 kg K/ha along with the cow dung@ 5 t/ha produced highest head yield of 75 t/ha.

Farooque and Islam (1989) conducted an experiment on the effect of spacing and different management practices on the growth and yield of cabbage. They reported that the highest marketable yield produced when 8.3 t FYM, 200 kg MOC, 326 kg Urea, 125 kg TSP and 200 kg MP per hectare were applied.

An experiment was conducted at Joydebpur, Gazipur on cabbage (var.Atlas-70) during the Rabi season to find out the effect of chemical fertilizer and manure (Anon.1985). There were five levels of nitrogen (0, 60, 120, 180 and 240 kg N/ha from urea), four levels of phosphorus (0, 60. 90 and 120 kg P20s/ha from TSP) and four levels of potassium (0, 60, 120 and 180 kg K_2O/ha from MP) along with cow dung@ 5 ton/ha. The head yield was increased with the increasing rate of NPK. The highest yield (110.98) t/ha was obtained from the combined effect of 180 kgN/ha, 120kg P_2O_5/ha and 120 kg K_2O/ha with 5 t/ha of cow dung.

In a two year trials, Samant *et. al.* (1981) studied the effects of different levels of N, P and K on yield of cabbage in Eastern Ghat Island zone of Orissa. N, P_2O_5 and/or K_2O were applied at 75-150: 40-80: 75-150 kg/ha in 27 different combinations. They reported that the best fertilizer combination was 75:80:150 kg/ha.

Nunung-Nurtica (1980) conducted an experiment to study the effects of NPK levels on the yield of cabbage. He found that on an andasol at Margahayu, N and K_2O at the rates of 90 and 100 kg/ha respectively gave the highest yield and at Cibodasy the highest yield was obtained with 135 and 150 kg N and K_2O /ha, respectively.

While carrying out an experiment on the fertilizer trial with N, P and K for white cabbage at Pasvicdalen, Samuelsen and Pettersen (1977) found that 200-270 kg N and 150 kg K_2O /ha gave higher growth and yield of cabbage.

2.3 Combined effect of phosphorus and potassium on the growth and yield of cabbage.

Devi and Singh (2012) set an experiment on varying levels of chemical fertilizers i.e. NPK and vermicompost significantly influenced the yield attributing characters and growth and biomass production in cabbage (*Brassica oleraceae* var.*capitata*) cv. Pride of India. There were six treatments (T_1: control i,e without any fertilizer; T_2: NPK @140:140:140 kg/ha; T_3: NPK@105:105:105 kg/ha + Vermicompost @ 1 ton/ha; T_4: NPK@70:70:70 kg/ha + Vermicompost @ 2tons/ha; T_5: NPK@35:35:35 kg/ha + Vermicompost @ 3 tons/ha; T_6: Vermicompost @ 4 tons/ha) each replicated four times. A maximum of 58.67% increase in yield over control was observed in a combined application of NPK and vermicompost in halves of their recommended doses.

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applied at 0, 100, 150 or 150 200 kg/ha, Pat 0, 50, 100 or 150 kg P_2O_5 and Kat 0, 75, 750 or 225 kg K_2O /ha in 12 combinations to cabbage cv. K-K cross. Gross yield and marketable head weight per plant were highest with 150 kg N+ 100 kg P_2O_5 + 150 kg K_2O or 200 kg N+ I 00 kg P_2O_5.

Jothi *et al.* (1993) carried out an experiment on the influence of N, P and Azospirillum on the yield of cabbage at Tamil Nadu in India. They reported that a cabbage yield of 117 .2 t/ha was obtained with the application of N, P and K at 100, 125 and 25 kg/ha respectively.

Aditya (1993) reported the highest yield (60 t/ha) of cabbage (Var. Atlas-70) during the Rabi season by applying 375 kg N/ha, 225 kg P/ha, 225 kg K/ha and cowdung @ 10 t/ha.

Aditya (1993) reported that the Rabi season cabbage (Var. Atlas-70) required 225 kg K./ha for its higher production.

Samant *et al.* (1992) investigated the balanced fertilizer use for cabbage in acid clay loam soils of Orissa, India. It was reported that nitrogen (75 Kg/ha): gave the highest yield (17.42 t/ha), and it was the economic dose.

Rao and Sbramanian (1991) conducted on experiment to find out the effect of potassium application on the yield and content of potassium, calcium and magnesium in cabbage at Bangalore in India. K_20 applied at 0, 25, 50 100, 150 and 200 kg/ha. They observed that the plant K concentration at all stages of growth increased significantly as the level of K_20 application dose.

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Yetistiren and Vural (1991) mentioned the effects of various fertilizer applications on cabbage yield and quality. Nitrogen was applied at 10 or 20 kg/ha and K at 15 or 30 kg K_2O /ha. They reported that highest yield was obtained with 20 kg N+ 30 K_2O /ha. They reported that highest yield was obtained with 20 kg N+ K_2O.

It was reported that the highest head yield of cabbage was obtained 76.64 t/ha from the combined effect of 180 kg N/ha, 60 kg P/ha, 180 kg K/ha and cowdung @ 5 t/ha (Anon, 1990) and it was stated that a combination of the fertilizer was important rather than application of a single for the production of cabbage.

Farooque and Islam (1989) conducted an experiment n the effect of spacing and different management practices on the growth and yield of cabbage. They reported that the highest marketable yield produced when 8.3 t FYM, 200 kg MOC, 326 kg Urea, 125 kg TSP and 200 kg MP per hectare were applied.

An experiment was conducted at Joydevpur, Gazipur on cabbage (var. Atlas-70) during the rabi season to find out the effect of chemical fertilizer and manure (Anon, 1985).There were five levels of nitrogen (0, 60, 120 and 240 kg N/ha from urea), four levels of phosphorus (0, 60, 90 and 120 kg P205/ha from TSP) and four levels of potassium (0, 60, 120 and 180 kg K_2O/ha from MP) along with cowdung @ 5 t/ha. The head yield increased with the increasing rate of N P K. The highest head of 110.98 t/ha was obtained from the combined effect of 180 kg N/ha, 120 kg K_2O/ha with 5 t/ha of cowdung.

In a 2 years trails, Samant *et al.* (1981) studied the effects of different levels of N P and Kon yield of cabbage in Eastern Ghat Highland zone of Orissa. N_2 P_2O_5 and/or K_2O were applied at 75-150:40-80:75-150 kg/ha in 27 different combinations. The economically best fertilizer combination at 75:80:150 kg/ha.

Nunung-Nurtika (1980) conducted an experiment to study the effects of NPK levels on the yield of cabbage. He found that on an andasol at Margahayu, N and

K_2O at the rate of 90 and 100 kg/ha respectively gave the highest yield and at obtained with 13 5 and 150 kg N and K_2O /ha respectively.

Nieuwhof (1969) mentioned dial the uptake of potassium was commonly greatest among the others element, followed closely by nitrogen in cabbage. Cabbage absorbed NPK at the rates of 100-350 kg, 21-49 kg and 149-249 kg/ha respectively.

Thus, it was evident from the reviews that fertilizer application promises higher yield and quality of cabbage. Growth and yield of cabbage are very much effected with the different levels of nitrogen and phosphorus application. It is very much important to find out appropriate dose of nitrogen and for the production of cabbage because it is a heavy feeder of nitrogen and phosphorus.

CHAPTER III

MATERIALS AND METHODS

This chapter illustrates information concerning methodology that was used in execution of the experiment. It comprises a short portrayal of location of experimental site, climatic condition, materials used for the experiment, treatments of the experiment, data collection procedure and statistical analysis etc. The details materials and methods of this experiment are presented below under the following headings:

3.1 Geographical location

The experimental area was situated at $23^0 77'$ N latitude and $90^0 33'$ E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.2 Agro-Ecological Region

The experimental site belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b).

3.3 Climate

Experimental site was located in the subtropical monsoon climatic zone, set aparted by winter during the months from October to February (Rabi season). Plenty of sunshine and moderately low temperature prevails during experimental period, which is suitable for cabbage growing in Bangladesh.

3.4 Soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment and analyzed from Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed for some important physical and chemical properties. The analytical data of the soil sample collected from the experimental area were determined (SRDI), Khamarbari, Dhaka and found 27% sand, 43% silt, 30% clay, organic matter 0.78% and details are presented in Appendix I.

3.5 Planting Materials

The variety of cabbage used in the experiment was "Atlas-70". The seeds were collected from a seed trader of China Seed Store, Dhaka.

3.6 Raising of Seedlings

Cabbage seedlings were raised in two seedbeds of 5 m x 1 m size. The soil was well prepared and converted into loose friable condition to obtain good tilt. All weeds, stubbles and dead root were removed. Twenty grams of seeds were sown in two seed bed. The seeds were sown in the seedbed on 22, November, 2012. Seeds were then covered with finished light soil and shading was provided by polyethylene sheets to protect the young seedlings from scorching sunshine and rainfall. Light watering, weeding and mulching were done as and when necessary to provide seedlings of a good condition for growth.

3.7 Treatments of the experiment

Two sets of treatments included in the experiment were as follows:

Factor A: Level of Phosphorus

In experiment, three different level of phosphorus were used. These were-

1. P_0 : Control
2. P_1 : 45 kg P_2O_5/ha
3. P_2 : 65 kg P_2O_5/ha

Factor B: Level of Potassium

Four potassium levels were used on experiment given below-

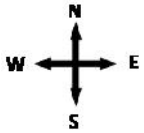
1. K_0 : Control
2. K_1 : 125 kg K_2O/ha
3. K_2 : 145 kg K_2O/ha
4. K_3 : 165 kg K_2O/ha

Treatment combinations:

There were 12 (4×3) treatments combination such as P_0K_0, P_0K_1, P_0K_2, P_0K_3, P_1K_0, P_1K_1, P_1K_2, P_1K_3 and P_2K_0, P_2K_1, P_2K_2, P_2K_3.

3.8 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of each plot was 1.8 m × 1.5 m. The distance between two adjacent replication (blocks), plot to plot distance and plant to plant distance were 0.5 m, 0.5 m and 50 cm × 40 cm, respectively. In each plot there were three rows having 12 (3×4) plants. The intra block and plot spaces will be used as irrigation and drainage channels. The layout of the experiment has been shown in Figure 1.



Factor A: Phosphorus

P_0 = Control
P_1 = 45 kg P_2O_5/ha
P_2 = 65 kg P_2O_5/ha

Factor B: Potassium

K_0 = Control
K_1 = 125 kg K_2O/ha
K_2 = 145 kg K_2O/ha
K_3 = 165 kg K_2O/ha

Figure 1. Layout of the experiment

3.9 Land preparation

The experiment plot was fallow at time of period of land preparation. The land was opened on 01 November, 2012 with the help of a power tiller and then it was kept open to sun for seven days prior to further ploughing cross ploughing followed by laddering. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was made into good tilth for transplanting the seedling.

3.10 Application of manures and fertilizers

Well decomposed cowdung was applied into the plots at the rate of 10 tons/ha and incorporated to the soil during final land preparation. The total amount of urea was applied as top dressed in ring method. 1st top dressed of one third was applied 15 days after transplanting and remainder urea was top [dressed in two equal installments at 30 and 45 days after transplanting. Triple Super Phosphate and Murate of potash were applied as basal dose in the plots as per treatment.

3.11 Transplanting of seedlings and gap filling

The seedbeds were watered one-hour before uprooting the seedlings to minimize the damage to the roots of the seedling. Healthy and 30 days old seedling were transplanted on 26 December, 2012. Transplanting was done in the afternoon. During transplanting of seedling, spacing between rows 50 cm. and plant 45 cm. were followed. 12 plants were transplanted in each unit plot. The seedlings were watered immediately after transplanting. To protect from scorching sunshine and unexpected rain, banana leaf sheath pieces were used over the transplanted seedlings. Shading and watering were continued until the seedlings were well established and it required for 5 days. The transplanted seedlings were kept under careful observation to find out any damage and dead seedling for its replacement. Replacement was done with healthy seedling having a boll of earth which was also planted on the scheduled date by the side of the unit plot. The transplants were watered up to one week for their establishment.

3.12 Intercultural operations

3.12.1 Irrigation

Three times flood irrigation was provided for the establishment of the crops in the plots and they were done after 15 days interval. Movement of water from sub plots were predicted from any possible leaching interface by providing ridges surrounding the plots.

3.12.2 Weeding, mulching and earthing up

Removal of weeds was done regularly whenever necessary to keep the plots free from weeds. Mulching was done as soon as the soil becomes workable after each irrigation. Earthing up was done on both sides of rows after 60 days of transplanting, using the soil from the space between the rows.

3.12.3 Pest management

Insect attack was a serious problem at the time of establishment of seeding in the field. Mole cricket, field cricket and cut warm attacked the young transplants. 'Basundin' was applied for controlling the soil born insects; some of the plants were attacked by aphids which were controlled by spraying 'Diazinon' 60 E.C at the rate of 560 ml per hectare. Few plants were infected by Alternaria leaf spot disease caused by *Altemaria brassicae.* To prevent the disease copper oxychloride (50%) at the rate of 1.36 kg per 450 liters of water was sprayed in the field.

3.12.4 Harvesting

The crop was harvesting during the period from 22th to 26th January, 2013, when the plants formed compact heads. Harvesting was done plot wise after testing the compactness or the cabbage head by thumb. The compact head showed comparatively a hard feeling. Each head was cut with sharp knife at the base of the plant.

3.13 Methods of collection data

When the heads were well compact, the plants were harvested at random from each unit plot. The observations pertaining to the following characters were recorded from 6 plants randomly selected in each plot. However, for gross and marketable yield per plot, all 12 plants of each unit plot were considered.

Periodical data i.e. data 20, 35, 50, 65 and 80 days after transplanting were taken for plant height, number of loose leaves, spread of plant and length of large leaf whereas the rest parameters were recorded at the time of harvest.

3.13.1 Plant height

Plant height was measured from the base of the plant to the top of the longest leaf ending lower older yellowish unfolded leaves of the plant at 80 DAT. A meter scale was used to measure the plant height and was taken in centimeters.

3.13.2 Number of the loose leaves

The number of loose leaves per plant was counted. Dead leaves were excluded during counting the leaves.

3.13.3 Dry weight

First the fresh weight of loose leaves per plan was recorded. Then one hundred grams of loose leaves were kept in the sun for 2 days then after dried in the oven at 70° c. for 72 hours until constant weight.

3.13.4 Whole plant weight

The whole weight of plant including the root and shoot was recorded at harvest in kilogram and average weight was taken.

3.13.5 Head weight

The whole weight of head was recorded at harvest in kilogram average weight was taken.

3.13.6 Head height

Head height was measured from the base of the plant to the top of the head at 65 80 DAT. A meter scale was used to measure the plant height and was taken in centimeters.

3.13.7 Yield/ plot

The total weight of cabbage plant excluding the roots in kilogram (kg) for determining the gross yield per plot was determined. All 12 plants of each plot were considered.

3.13.8 Yield (t/ha)

The gross yield of cabbage per hectare was converted in metric tonnes from the yield per plot

3.13.9 Head cross section (length)

The collected head was first cross sectioned by knife and then the length of cross section was measured by meter scale.

3.13.10 Head cross section (width)

The collected head was first cross sectioned by knife and then the width of cross section was measured by meter scale.

3.14 Statistical Analysis

Collected data were statistically analyzed using MSTAT-C computer package programme. Mean for every treatments were calculated and analysis of variance for each one of characters was performed by F–test (Variance Ratio). Difference between treatments was assessed by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

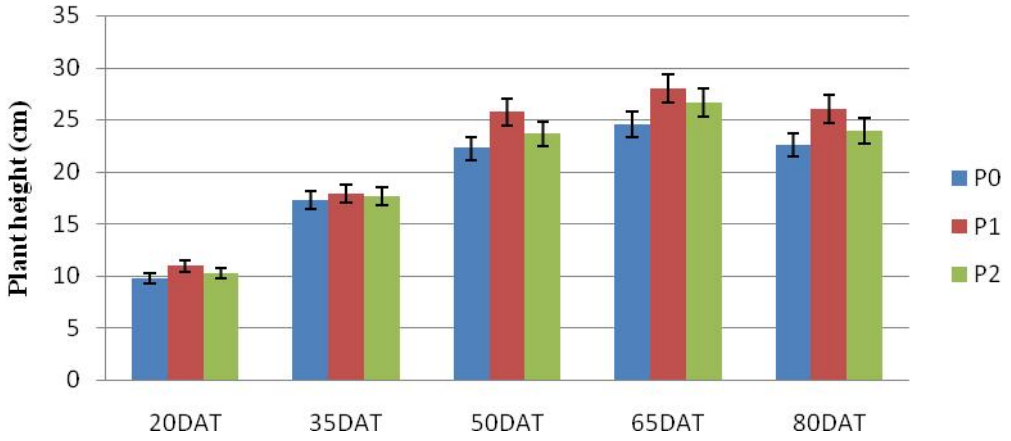
CHAPTER IV

RESULTS AND DISCUSSION

The research work was accomplished to investigate the effect of phosphorus and potassium on growth and yield of cabbage. Some of the data have been presented and expressed in table(s) and others in figures for easy discussion, comparison and understanding. The analysis of variance of data respect of all the parameters has been shown in Appendix. The results of each parameter have been discussed and possible interpretations where ever necessary have been given under following headings.

4.1 Plant height

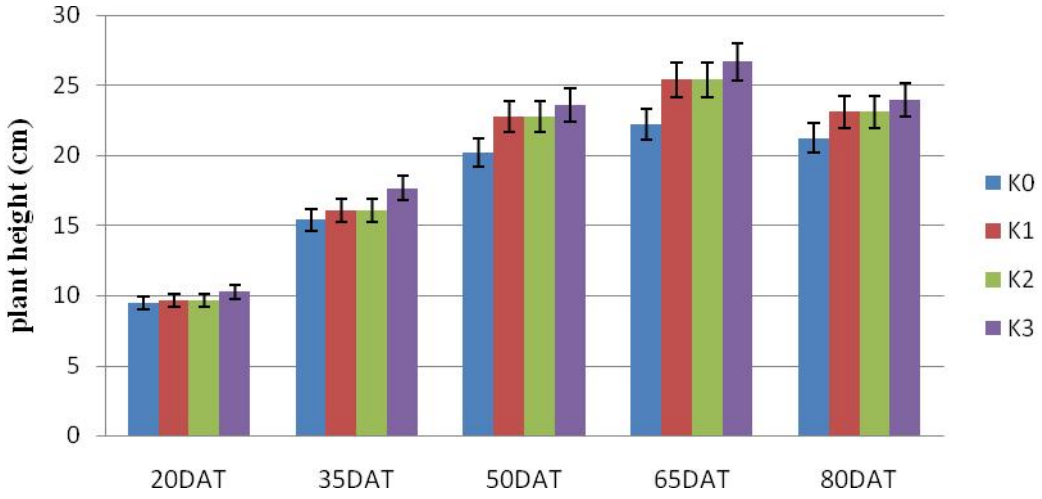
Plant height was significantly affected by different levels of phosphorus (Figure 2 & Appendix III). Plant height of cabbage exposed statistically significant among control (P_0), 45 kg P_2O_5/ha (P_1) and 65 kg P_2O_5/ha (P_2) phosphorus at 20, 35, 50 and 80 DAT. It was observed that the P_1 produced the highest plant height (10.96 cm, 17.88 cm, 25.7 cm, 27.98 cm and 26.03 cm) at 20, 35, 50 and 80 DAT respectively. However P_0 (control) produced the lowest plant height (9.75 cm, 17.24 cm, 22.6 cm, 24.56 cm and 22.59 cm) at 20, 35, 50 and 80 DAT respectively. Sing *et al.* (1988) found similar trend of results in their study.



P_0= control, P_1= 45 kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha

Figure 2. Effect of phosphorus on the plant height of cabbage.

A significant variation was found due to application of different levels of potassium on plant height (Figure 3 & Appendix III). The highest plant height (10.26 cm, 17.64 cm, 23.62 cm, 26.66 cm and 23.95 cm) of cabbage were recorded from K_3 (165 kg K_2O/ha) at 20, 35, 50, 65 and 80 DAT respectively, and K_0 (control) treatment produced the lowest plant height (9.44 cm, 15.4 cm, 20.2 cm, 22.22 cm and 21.22 cm) at 20, 35, 50, 65 and 80 DAT respectively. The results ensures maximum plant nutrients in available from potassium which help proper growth of plant and the results are the highest plant height. Rao and Subramaniun (1991) observed that the plant K concentration at all stages of growth increased significantly at the increased level of K_2O application. Tianxiu *et al.* (1994) also agreed to the present findings of the results.



K_0= control, K_1= 125 kg K_2O/ha, K_2= 145kg K_2O/ha and K_3=165 kg K_2O/ha

Figure 3. Effect of potassium on the plant height of cabbage.

There was no significant variation recorded on plant height of cabbage due to combination effect of different levels of phosphorus and potassium at different days after transplanting (Table 1 & Appendix III). However treatment combination of P_1K_3 gave the highest plant height and control P_0K_0 produced the lowest plant height at all observation. From the results it was revealed that phosphorus and potassium favored the plant height in comparison with the control. Both the fertilizer increased plant height up to a considerable level after then plant height decreased with a decreasing trend.

Table 1. Combination effect of phosphorus and potassium on plant height of cabbage

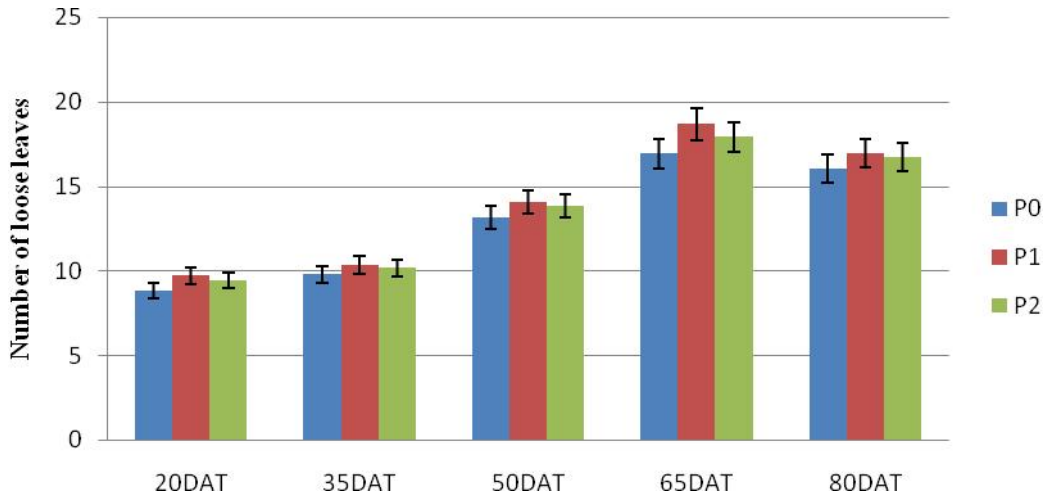
Treatments	Days After Transplanting				
	20	**35**	**50**	**65**	**80**
P_0K_0	9.233	15.53	20.80	23.33	21.13
P_0K_1	9.667	16.80	21.90	24.22	22.23
P_0K_2	9.933	18.20	22.27	24.33	22.60
P_0K_3	10.17	18.43	24.07	26.33	24.40
P_1K_0	10.00	16.60	24.87	26.90	25.20
P_1K_1	10.77	17.47	25.07	27.10	25.40
P_1K_2	11.42	18.13	26.13	28.73	26.47
P_1K_3	11.67	19.30	26.73	29.17	27.07
P_2K_0	9.700	16.01	22.60	25.93	22.93
P_2K_1	10.00	17.28	23.27	26.25	23.60
P_2K_2	10.33	18.47	23.80	26.49	24.13
P_2K_3	11.00	18.79	24.80	27.95	25.13
$LSD_{(0.05)}$	2.301^{ns}	3.08^{ns}	5.814^{ns}	5.263^{ns}	5.814^{ns}
CV %	9.15	8.56	10.67	8.85	10.43

P_0= control, P_1= 45kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha,

K_0= control, K_1= 125 kg K_2O/ha, K_2= 145kg K_2O/ha and K_3=165 kg K_2O/ha

4.2 Number of loose leaves

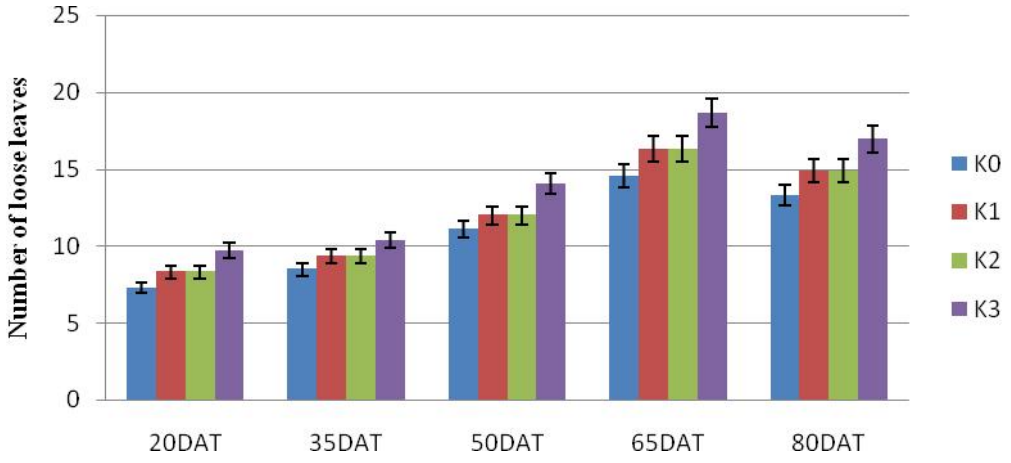
Number of loose leaves of cabbage varied significantly due to use of different levels of phosphorus (Figure 4 & Appendix IV). It was observed that the P_1 (45 kg P_2O_5/ha) produced the highest number of leaves (9.71, 10.37, 14.07, 18.67 and 16.95) at 20, 35, 50, 65 and 80 DAT respectively. However P_0 (control) produced the lowest number of leaves (8.83, 9.76, 13.17, 16.92 and 16.05) at 20, 35, 50, 65 and 80 DAT respectively. Warg-Zhaottui and Li-Shengkiu (2004) stated that phosphorus produced the highest number of leaves with in the certain levels.



P_0= control, P_1= 45 kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha

Figure 4. Effect of phosphorus on the number of loose leaves of cabbage.

Due to application of different levels of potassium showed significant variation on number of loose leaves at different days after transplanting of cabbage plant (Figure 5 & Appendix IV). The maximum number of loose leaves 9.71, 10.37, 14.07, 18.67 and 16.95 was recorded from K_3 (165 kg K_2O/ha) treatments at 20, 35, 50, 65 and 80 DAT respectively. Whereas the minimum numbers 7.3, 8.5, 11.11, 14.55 and 13.33 was produced by K_0 (control) at all observation. From the above result it was showed that Potassium enhances plant growth resulting the plant produced the highest number of loose leaves. Sing and Naik (1988) found similar trend of results which supported to the present findings.



K_0= control, K_1= 125 kg K_2O/ha, K_2= 145 kg K_2O/ha and K_3=165 kg K_2O/ha

Figure 5. Effect of potassium on the number of loose leaves of cabbage.

The various treatment combinations of different levels of phosphorus and potassium had no significant variation on the number of loose leaves of cabbage (Table 2 & Appendix IV). However it was observed that the treatment combinations of P_1K_3 produced the highest number of loose leaves and P_0K_0 produced the lowest number of loose leaves at all days after transplanting.

Table 2. Combination effect of phosphorus and potassium on the number of loose leaves of cabbage

Treatments	Days After Transplanting				
	20	**35**	**50**	**65**	**80**
P_0K_0	7.33	8.87	10.67	15.33	13.55
P_0K_1	8.33	9.33	13.67	16.33	16.55
P_0K_2	9.53	10.47	13.80	17.67	16.25
P_0K_3	10.13	10.40	14.53	18.33	17.41
P_1K_0	8.93	9.40	12.73	17.00	15.61
P_1K_1	9.20	10.07	14.00	18.33	16.88
P_1K_2	10.00	10.33	14.17	19.00	17.05
P_1K_3	10.73	11.67	15.40	20.33	18.28
P_2K_0	8.73	9.80	12.60	16.67	15.48
P_2K_1	8.87	9.47	14.07	17.67	16.95
P_2K_2	9.93	10.13	14.47	18.33	17.35
P_2K_3	10.27	11.20	14.17	19.00	17.05
$LSD_{(0.05)}$	2.122^{ns}	1.444^{ns}	2.046^{ns}	2.907^{ns}	2.182^{ns}
CV %	11.53	9.47	7.75	8.40	7.04

P_0= control, P_1= 45 kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha,

K_0= control, K_1= 125 kg K_2O/ha, K_2= 145 kg K_2O/ha and K_3=165 kg K_2O/ha

4.3 Dry weight

Dry weight of cabbage did not show the significant differences due to use of different levels of phosphorus (Table 3 & Appendix VI). However, P_1 (45kg P_2O_5/ha) produced the highest dry weight (7.73 g) and P_0 (control) produced the lowest dry weight (7.02 g) of cabbage.

Dry weight of cabbage varied significantly due to application of different levels of potassium (Table 3 & Appendix VI). K_3 (165 kg K_2O/ha) performed the highest dry weight (8.50 g) of cabbage which was statistically similar to and K_1 (7.13 g) whereas K_0 (control) produced the lowest dry weight (6.16 g) which was statistically similar to K_1 (7.13 g) and K_2 (7.43 g).

Due to combination effect of different levels of phosphorus and potassium dry weight of cabbage did not show the significant variation (Table 3 & Appendix VI). Treatment combination of P_1K_3 performed the highest dry weight (9.36 g) and P_0K_0 gave the lowest (6.02 g) dry weight. Devi and Sing (2012) agreed to the findings of the present study.

4.4 Whole plant weight

Whole plant weight of cabbage varied significantly due to different levels phosphorus (Table 3 & Appendix VI). The highest whole plant weight (2.58 kg) was found from P_1 (45kg P_2O_5/ha) which was similar (2.37 kg) to P_2 and the lowest (2.23 kg) was recorded from P_0 (control) which was also statistically similar to P_2 (2.23 kg).

A significant variation was observed on whole plant weight of cabbage due to application of different levels of potassium (Table 3 & Appendix VI). K_3 (165 kg K_2O/ha) produced the highest whole plant weight (2.63 kg) of cabbage which was statistically similar to K_2 (2.56 kg) and the K_0 (control) gave the lowest whole plant weight (2.17 kg) which was statistically similar to K_1 (2.24 kg). Bojokalfa *et al.* (2003) agreed to the findings of the present study.

Whole plant weight of cabbage varied significantly due to various treatment combinations of phosphorus and potassium (Table 3 & Appendix VI). Treatment combination of P_1K_3 produced the highest whole plant weight (2.86 kg) which was statistically similar to P_1K_2 (2.78 kg), P_2K_2 (2.54 kg) and P_2K_3 (2.64 kg) and the lowest (2.05 kg) was found from P_0K_0.

4.5 Head weight

Head weight of cabbage varied significantly due to application of different levels of phosphorus (Table 3 & Appendix VI). The highest head weight (1.84 kg) was obtained from P_1 (45kg P_2O_5/ha) which was statistically similar to P_2 (1.71 kg) and the lowest (1.64 kg) was found from P_0 (control). Yetistiren and Vural (1991) stated that head weight of cabbage was increased up to certain level of phosphorus.

Head weight of cabbage varied significantly due to application of different levels of potassium (Table 3 & Appendix VI). Treatment K_3 (165 kg K_2O/ha) produced the highest head weight (1.86 kg) of cabbage which was statistically similar to K_2 (1.80 kg) and K_1 (1.70 kg). The lowest head weight (1.64 kg) of cabbage was recorded from K_0 (control) which was statistically similar with K_1 (1.70 kg).

Due to combination effect of different levels of phosphorus and potassium head weight of cabbage did not show significant variation (Table 3 & Appendix VI). Treatment combination P_1K_3 produced the highest head weight (1.95 kg) and the lowest head weight (1.52 kg) of cabbage recorded from P_0K_0 treatment combination.

Table 3. Effect of phosphorus, potassium and their combinations effects on the dry weight, whole plant weight and head weight of cabbage

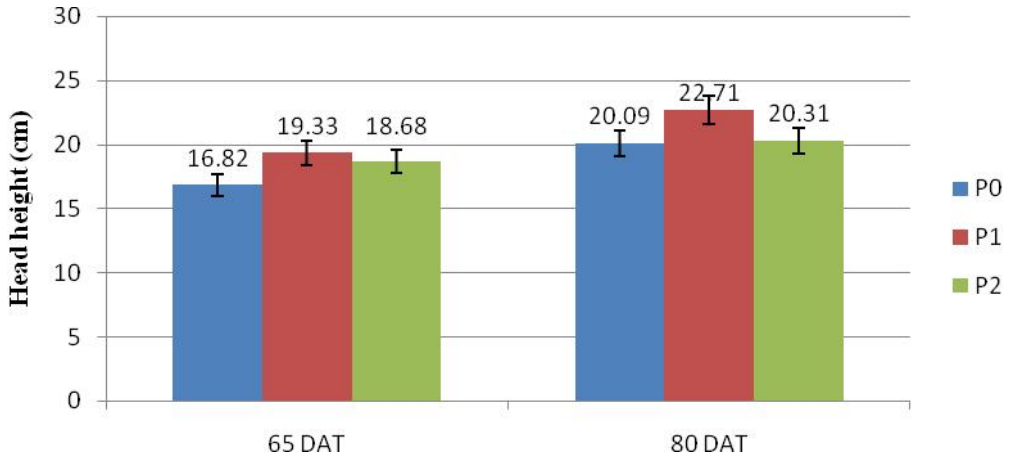
Treatments	Dry weight (g)	Whole plant weight (kg)	Head weight (kg)
Effect of phosphorus			
P_0	7.02	2.23 b	1.64 b
P_1	7.73	2.58a	1.84a
P_2	7.16	2.37ab	1.71ab
$LSD_{0.05}$	1.335^{ns}	0.2454	0.1855
CV %	10.22	9.23	10.14
Effect of potassium			
K_0	6.16 b	2.17 b	1.58 b
K_1	7.13ab	2.24 b	1.72ab
K_2	7.44ab	2.56a	1.83a
K_3	8.50a	2.63a	1.85a
$LSD_{0.05}$	1.54	0.28	0.21
CV %	10.22	9.23	10.14
Combination effect of phosphorus and potassium			
P_0K_0	6.02	2.05 e	1.52
P_0K_1	6.97	2.14 de	1.62
P_0K_2	7.13	2.33 c-e	1.73
P_0K_3	7.97	2.39 b-e	1.69
P_1K_0	6.00	2.30 c-e	1.68
P_1K_1	7.47	2.41 b-e	1.86
P_1K_2	8.11	2.78 ab	1.87
P_1K_3	9.37	2.87 a	1.95
P_2K_0	6.47	2.16 de	1.53
P_2K_1	6.97	2.18 de	1.62
P_2K_2	7.07	2.54 a-d	1.81
P_2K_3	8.17	2.64 a-c	1.89
$LSD_{(0.05)}$	2.669^{ns}	0.37	0.371^{ns}
CV %	10.22	9.23	10.14

P_0= control, P_1= 45 kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha,

K_0= control, K_1= 125 kg K_2O/ha, K_2= 145kg K_2O/ha and K_3=165 kg K_2O/ha

4.6 Head height

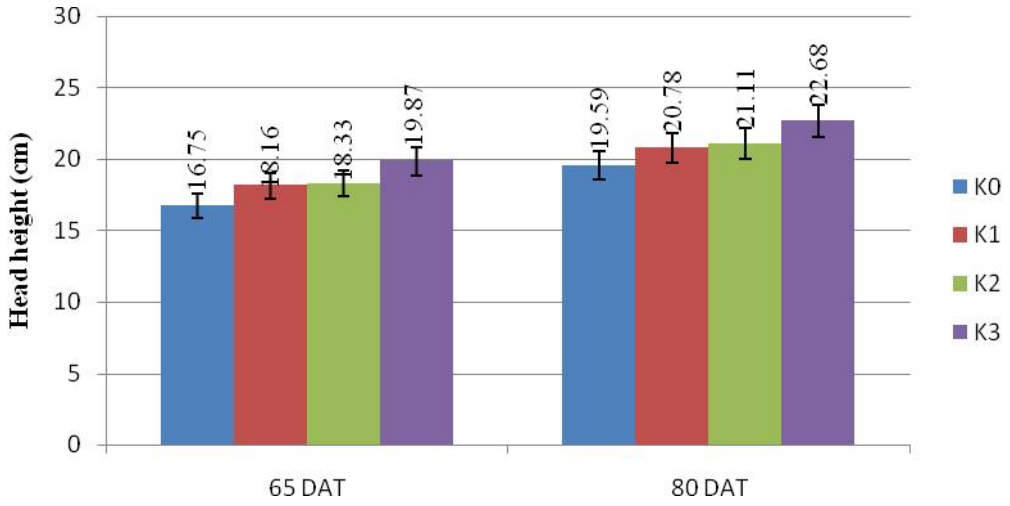
Head height of cabbage varied significantly due to application of different levels of phosphorus (Figure 6 & Appendix V). At 65 DAT P_1 (45kg P_2O_5/ha) produced the highest head height (19.33 cm) which was statistically similar to P_2 (18.68 cm) and P_0 (control) treatment produced the lowest head height (16.82 cm) of cabbage. At 80 DAT, P_1 produced the highest head height (22.71 cm) and P_0 (control) treatment produced the lowest head height (20.09 cm) which was statistically similar with P_2 (20.31 cm). Bolland & Gilkes, 1998 agreed to the present results.



P_0= control, P_1= 45kg P_2O_5/ha, P_2= 65kg P_2O_5/ha

Figure 6. Effect of phosphorus on the head height of cabbage.

Head height of cabbage also varied significantly due to application of different levels of potassium (Figure 7 & Appendix V). At 65 DAT, K_3 produced the highest head height (19.87 cm) of cabbage and K_0 (control) produced the lowest head height (16.75 cm). At 80 DAT, K_3 (165 kg K_2O/ha) gave the highest head height (22.68 cm) which was statistically similar to K_2 (21.11 cm) and K_0 (control) produced the lowest head height (19.59 cm) which was statistically similar with K_1 (20.78 cm) and K_2 (20.78 cm). Cox *et al.*, 1999 found similar trend of results which supported to the present study.



K_0= control, K_1= 125 kg K_2O/ha, K_2= 145kg K_2O/ha and K_3=165 kg K_2O/ha

Figure 7. Effect of potassium on the head height of cabbage.

Head height of cabbage varied significantly due to combined effect of different levels of phosphorus and potassium (Table 4 & Appendix V). At 60 DAT, P_1K_3 produced the highest head height (21.29 cm) which was statistically similar to P_1K_1 (19.56 cm) and P_2K_3 (20.00 cm) while the lowest head height (15.58 cm) recorded from P_oK_0 treatment combination. At, 80 DAT P_1K_3 produced the highest head height (24.32 cm) which was statistically similar with P_0K_3 (27.75 cm), P_1K_1 (22.92 cm), P_1K_2 (22.71 cm) and P_2K_3 (21.96 cm) whereas the lowest (18.81 cm) was recorded from P_0K_0.

Table . 4 Combination effect of phosphorus, potassium on the head height at different days after transplanting

Treatments	**Head height (cm)**	
	65 DAT	**80 DAT**
Combination effect of phosphorus and potassium		
P_0K_0	15.58 f	18.81 d
P_0K_1	16.42 ef	19.50 cd
P_0K_2	16.96 d-f	20.32 b-d
P_0K_3	18.31 b-d	21.75 a-d
P_1K_0	17.00 d-f	20.88 b-d
P_1K_1	19.56 ab	22.92 ab
P_1K_2	19.46 bc	22.71 a-c
P_1K_3	21.29 a	24.32 a
P_2K_0	17.67 c-e	19.07 d
P_2K_1	18.50 b-d	19.91 b-d
P_2K_2	18.57 b-d	20.31 b-d
P_2K_3	20.00ab	21.96 a-d
$LSD_{(0.05)}$	1.674	2.886
CV %	5.41	8.1

P_0= control, P_1= 45kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha,
K_0= control, K_1= 125 kg K_2O/ha, K_2= 145kg K_2O/ha and K_3=165 kg K_2O/ha

4.7 Head cross section length (cm)

Head cross section length of cabbage varied significantly due to application of different levels of phosphorus (Table 5 & Appendix V). The highest head cross section length (12.52 cm) found from P_1 (45kg P_2O_5/ha) treatment which was statistically similar to P_2 (12.20 cm) and the lowest head cross section length (11.72 cm) of cabbage recorded from P_0 (control) which was also statistically similar with P_2 (12.20 cm).

Head cross section length of cabbage did not varied significantly due to application of different levels of potassium (Table 5 & Appendix VI). Treatment K_3 (165 kg K_2O/ha) produced the highest head cross section length (12.53 cm) and K_0 (control) produced the lowest head cross section length (11.67 cm) of cabbage.

Head cross section length of cabbage did not varied significantly due to various treatment combinations of phosphorus and potassium (Table 5 & Appendix V). Treatment combination of P_1K_3 produced the highest head cross section length (12.80 cm) and P_0K_0 produced the lowest head cross section length (11.07 cm) of cabbage.

4.8 Head cross section width

Head cross section width of cabbage did not show the significant variation due to application of different levels of phosphorus (Table 5 & Appendix V). The highest head cross section width (19.17 cm) was performed from P_1 (45kg P_2O_5/ha) and P_0 (control) produced the lowest head cross section width (18.25 cm) of cabbage.

Due to application of different levels of potassium showed significant variation on head cross section width of cabbage (Table 5 & Appendix V). The highest head cross section width (19.78 cm) was recorded from K_3 (165 kg K_2O/ha) which was statistically similar to K_2 (19.44 cm) and K_1 (18.56 cm) where as the lowest (17.22 cm) was found from K_0 (control) treatment.

Head cross section width of cabbage did not varied significantly due to various treatment combinations of phosphorus and potassium (Table 5 & Appendix V). However treatment combination of P_1K_3 produced the highest head cross section width (20.33 cm) and the lowest head cross section width (16.67 cm) of cabbage was obtained from the treatment combination of P_0K_0.

Table . 5 Effect of phosphorus and potassium and their combination effect on the head cross section

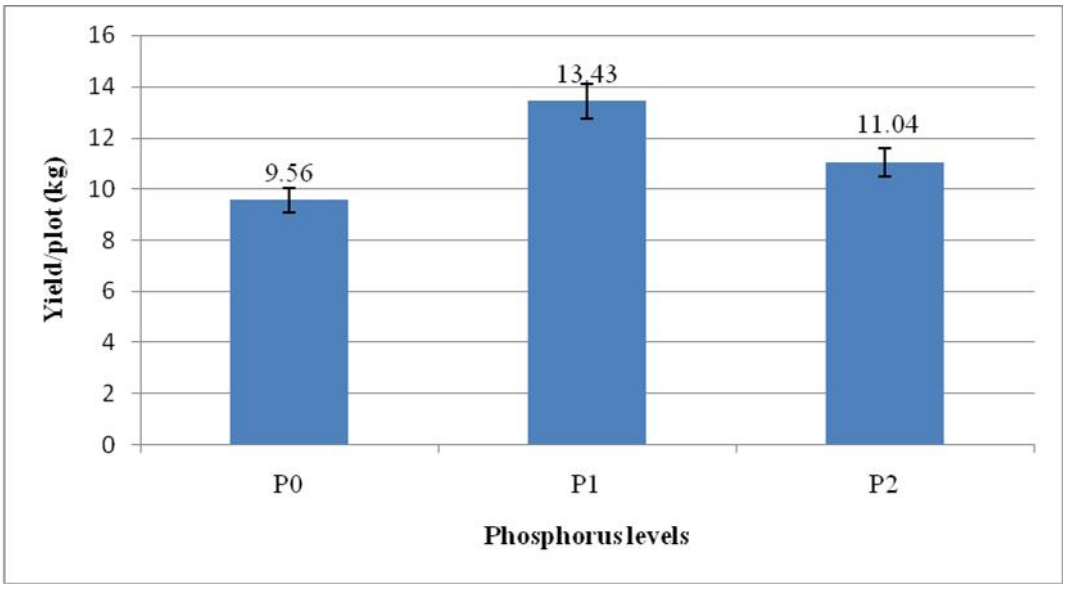
Treatments	Head cross section (length)	Head cross section (width)
Effect of phosphorus		
P_0	11.72 b	18.25
P_1	12.52a	19.17
P_2	12.20ab	18.83
$LSD_{0.05}$	0.6431	1.656^{ns}
CV %	6.26	10.43
Effect of potassium		
K_0	11.67	17.22 b
K_1	12.06	18.56ab
K_2	12.33	19.44 a
K_3	12.53	19.78 a
$LSD_{0.05}$	0.742^{ns}	1.912
CV %	6.26	10.43
Combination effect of phosphorus and potassium		
P_0K_0	11.07	16.67
P_0K_1	11.67	18.00
P_0K_2	12.04	19.00
P_0K_3	12.11	19.33
P_1K_0	12.10	17.67
P_1K_1	12.52	18.67
P_1K_2	12.67	20.00
P_1K_3	12.80	20.33
P_2K_0	11.83	17.33
P_2K_1	12.00	19.00
P_2K_2	12.29	19.33
P_2K_3	12.67	19.67
$LSD_{(0.05)}$	1.286^{ns}	3.312^{ns}
CV %	6.26	10.43

P_0= control, P_1= 45kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha,

K_0= control, K_1= 125 kg K_2O/ha, K_2= 145kg K_2O/ha and K_3=165 kg K_2O/ha

4.9 Yield/Plot

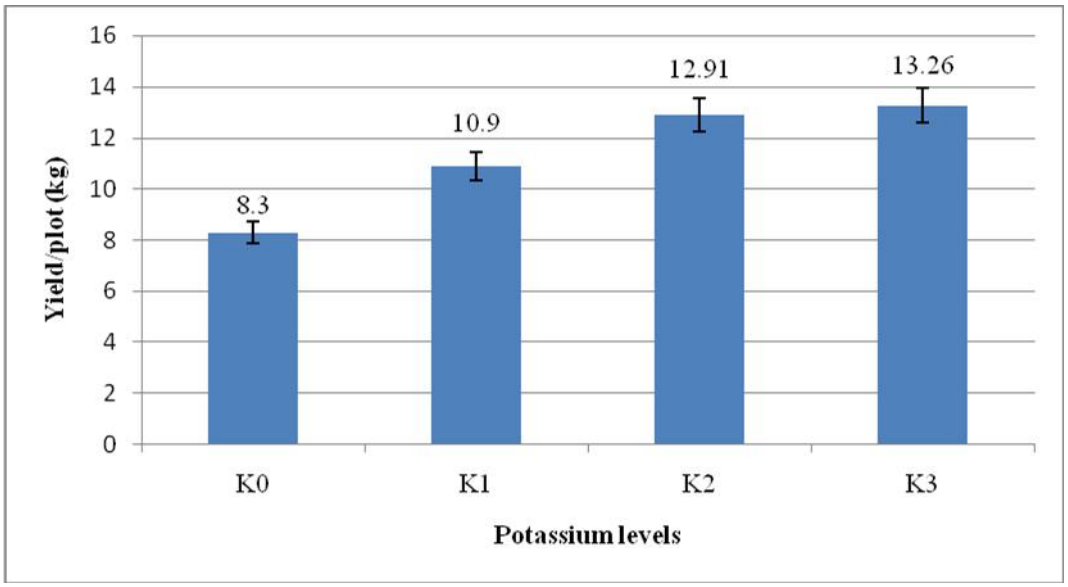
Yield/plot of cabbage varied significantly due to application of different levels of phosphorus levels of treatments (Figure 8 & Appendix VI). It was observed that P_1 (45 kg P_2O_5/ha) produced the highest yield/plot (13.43 kg) of cabbage and P_0 (control) produced the lowest yield/plot (9.56 kg) of cabbage. Hossain *et al*. (2011) also reported that 45 kg P_2O_5/ha produced best cabbage yield.



P_0= control, P_1= 45kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha,

Figure 8. Effect of phosphorus on the yield/plot of cabbage.

Significant variation was found due to application of different levels of potassium on yield/plot of cabbage (Figure 9 & Appendix VI). However, the highest yield/plot (13.26 kg) was produced by K_3 (165 kg K_2O/ha) treatment which was statistically similar to K_2 (12.91 kg) whereas the lowest yield (8.3 kg) was performed by control (K_0). The present results also supported to the findings of Hossain *et al*. (2011).



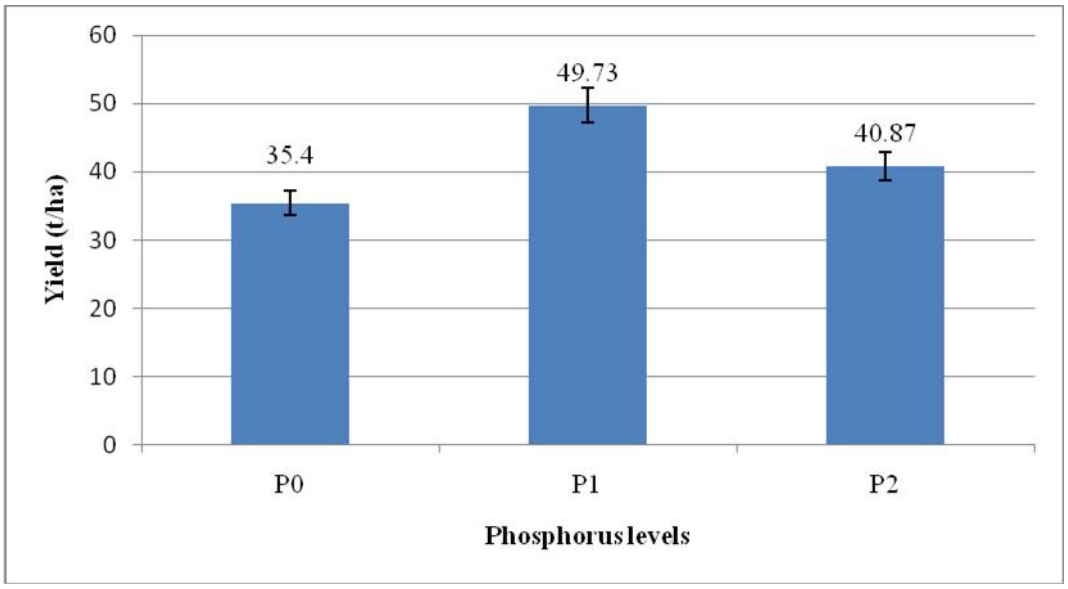
K_0= control, K_1= 125 kg K_2O/ha, K_2= 145kg K_2O/ha and K_3=165 kg K_2O/ha

Figure 9. Effect of potassium on the yield/plot of cabbage.

Yield/plot of cabbage varied significantly due to treatment combinations of phosphorus and potassium (Table 6 & Appendix VI). P_1K_3 produced the highest yield/plot (7.59 kg) which was statistically similar to P_1K_1 (12.93 kg) and P_1K_2 (15.87 kg). However, P_0K_0 produced the lowest yield (7.59 kg) which was statistically similar to P_2K_0 (8.38 t/ha) and P_2K_1 (10.75 t/ha).

4.10 Yield (t/ha)

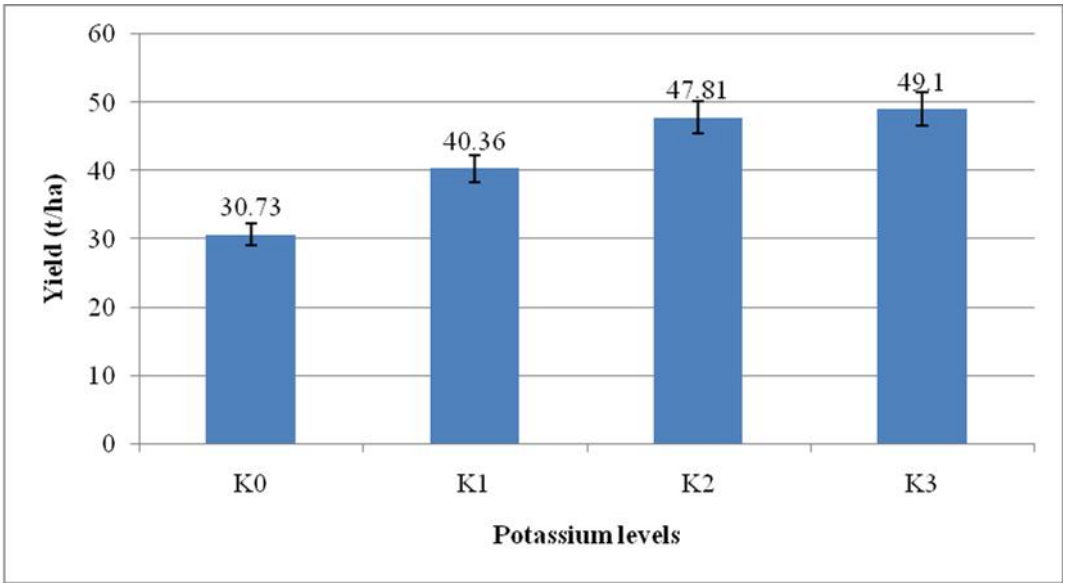
Yield of cabbage varied significantly due to application of different levels of phosphorus levels of treatments (Figure 10 & Appendix VI). It was observed that P_1 (45kg P_2O_5/ha) produced the highest yield (49.73 t/ha) of cabbage and P_0 (control) produced the lowest yield (35.4 t/ha) of cabbage. Hossain *et al*. (2011) also reported that 45 kg P_2O_5/ha produced best cabbage yield.



P_0= control, P_1= 45kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha,

Figure 10. Effect of phosphorus on the yield of cabbage.

Significant variation was found due to application of different levels of potassium on yield/plot of cabbage (Figure 11 & Appendix VI). However, the highest yield (49.1 t/ha) was produced by K_3 (165 kg K_2O/ha) treatment which was statistically similar to K_2 (47.81 t/ha) whereas the lowest yield (30.73 t/ha) was performed by control (K_0). The present results also supported to the findings of Hossain *et al*. (2011).



K_0= control, K_1= 125 kg K_2O/ha, K_2= 145kg K_2O/ha and K_3=165 kg K_2O/ha

Figure 11. Effect of potassium on the yield of cabbage.

Yield of cabbage varied significantly due to treatment combinations of phosphorus and potassium (Table 6 & Appendix VI). P_1K_3 produced the highest (59.22 t/ha) yield which was statistically similar to P_1K_1 (47.89 t/ha) and P_1K_2 (58.78 t/ha) and P_2K_3 (48.11 t/ha). However, P_0K_0 produced the lowest yield (28.11 t/ha) which was statistically similar to P_0K_1 (35.22 t/ha) and P_2K_0 (31.04 t/ha).

Table . 6 Combination effects of phosphorus and potassium on the yield/plot and yield of cabbage

Treatments	Yield/plot (kg)	Yield (t/ha)
P_0K_0	7.59 g	28.11 f
P_0K_1	9.51 ef	35.22 ef
P_0K_2	10.34 cd	38.30 d
P_0K_3	10.79 cd	39.96 cd
P_1K_0	8.92 bc	33.04 bc
P_1K_1	12.93 ab	47.89 ab
P_1K_2	15.87 a	58.78 a
P_1K_3	15.49 a	59.22 a
P_2K_0	8.38 fg	31.04 ef
P_2K_1	10.75 fg	37.96 de
P_2K_2	12.02 de	46.37 bc
P_2K_3	12.99 cd	48.11 ab
$LSD_{(0.05)}$	1.131	4.43
CV %	8.75	9.78

P_0= control, P_1= 45kg P_2O_5/ha, P_2= 65 kg P_2O_5/ha,

K_0= control, K_1= 125 kg K_2O/ha, K_2= 145kg K_2O/ha and K_3=165 kg K_2O/ha

CHAPTER V

SUMMERY AND CONCLUSION

The experiment was conducted in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2012 to February 2013 to study the effect of phosphorus and potassium on growth and yield of cabbage. The experiment considered of two factors. Factor A: Phosphorous (3 levels) Control, 50 kg and 65 kg P_20_5/ha; Factor B: Potassium (4 levels), Control, 125 kg, 145 kg and 165 kg K_2O /ha. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield components and yield of cabbage were recorded.

Looking upon the phosphorus treatments the highest plant height and the maximum number of loose leaves (18.67, at 65 DAT) was recorded from P_1, on the other hand lowest plant height and minimum number of loose leaves (16.92, at 65 DAT) found from P_0 (control) treated plant in all DAT. Whereas observing the potassium treatment K_3 produced highest plant height and maximum number of loose leaves (18.67, at 65 DAT) while K_0 (control) produced the lowest plant height and minimum number of loose leaves (14.55, at 65 DAT) in all DAT. In case of combination effect of phosphorus and potassium the highest plant height and maximum number of loose leaves (20.33, at 65 DAT) was recorded from P_1K_3 while lowest plant height and minimum number of loose leaves (15.33, at 65 DAT) recorded from P_0K_0 treatment in all DAT.

Considering the phosphorus treatments the maximum dry weight, highest whole plant weight, head height recorded from P_1 and P_0 (control) produced the lowest dry weight, lowest whole plant weight of cabbage. In case of potassium treatments K_3 produced the highest dry weight, whole plant weight and head height while K_0 (control) produced the lowest dry weight, whole plant weight and head height. In

combination effect of phosphorus and potassium P_1K_3 produced the highest dry weight, whole plant weight and head height while P_0K_0 produced the lowest dry weight, whole plant weight and head height of cabbage

Looking upon the phosphorus treatments P_1 produced the highest head cross section length and width while P_0 (control) produced the lowest head cross section length and width of cabbage. On the other hand K_3 produced the highest head cross section length and width whereas K_0 (control) produced the lowest head cross section length and width of cabbage. In combination of P_1K_3 produced the highest head cross section length and width while P_0K_0 produced the lowest head cross section length and width of cabbage.

Considering the phosphorus treatments the maximum head weight and yield recorded from P_1 while P_0 produced the minimum. In case of potassium treatment the maximum head weight and yield recorded from K_3 while K_0 produced the minimum. In combination of P_1K_3 produced the maximum head weight and yield whereas P_0K_0 produced the minimum head weight and yield of cabbage.

Considering the results of the present experiment, it may conclude that P and K positively influenced the entire physiology, growth and yield of cabbage. In all stage of growth and yield 45 kg/ha phosphorus (P_1) gave better result on the other hand 165 kg/ha potassium produced height growth and yield. So, it may be recommended that 45 kg K_2O/ha phosphorus (P_1) with 165 kg P_2O_5/ha potassium (K_3) better for growth and yield of cabbage. The experiment was done only one growing season, for more confirmation of the result such type of experiment is required before recommendation. Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. Another level of phosphorus and potassium fertilizer may be used for identifying more accurate doses.
3. Different fertilizers may be included for attaining better results.

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APPENDICES

Appendix I. Characteristics of experimental field soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from September to December, 2012

Month (2012)	*Air temperature (^{o}C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
October	26.5	19.4	81	22
November	25.8	16.0	78	00
December	22.4	13.5	74	00
January	20.4	9.5	75	00

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1212

Appendix III. Mean square values for plant height of cabbage at different days after transplanting

Sources of variation	DF	Plant height (cm)				
		20DAT	35DAT	50DAT	65DAT	80DAT
Replication	2	3.316	1.167	60.091	70.001	50.556
Phosphorus (A)	2	3.110*	1.672 *	25.110*	26.61*	25.162*
Potassium (B)	3	2.136*	10.126*	8.182 *	12.150 *	10.623*
A x B	6	0.726 ^{ns}	0.245 ^{ns}	0.870 ^{ns}	0.939 ^{ns}	1.061 ^{ns}
Error	22	1.001	3.926	3.336	5.451	8.103

*Significant at 5% level
ns- Non significant

Appendix IV. Mean square values for number of loose leaves of cabbage at different days after transplanting

Sources of variation	DF	No. of loose leaves				
		20DAT	35DAT	50DAT	65DAT	80DAT
Replication	2	1.172	1.996	1.572	1.831	0.919
Phosphorus (A)	2	2.126 ^{ns}	2.032 ^{ns}	3.553*	10.25*	3.898*
Potassium (B)	3	8.40*	6.655*	8.505*	8.626*	7.709*
A x B	6	0.293 ^{ns}	0.441 ^{ns}	2.820 ^{ns}	0.592 ^{ns}	1.712 ^{ns}
Error	22	1.571	0.727	1.46	2.947	1.46

*Significant at 5% level
ns- Non significant

Appendix V. Mean square values for head height, head cross section length and width of cabbage at different days after transplanting

Sources of variation	DF	Head height (cm)		Head cross section length (cm)	Head cross section width (cm)
		65DAT	80DAT		
Replication	2	3.631	15.654	2.929	14.123
Phosphorus (A)	2	31.317*	20.606*	2.003*	3.610 ^{ns}
Potassium (B)	3	18.616*	21.170*	1.796 ^{ns}	14.418*
A x B	6	1.062*	0.963*	0.728 ^{ns}	0.883 ^{ns}
Error	22	1.157	1.896	0.998	2.527

*Significant at 5% level
ns- Non significant

Appendix VI. Mean square values for dry weight, whole plant weight, head weight and yield of cabbage at different days after transplanting

Sources of variation	DF	Dry weight (g)	Whole plant weight (kg)	Yield/plot (kg)	Yield (t/ha)
Replication	2	2.919	0.332	0.09	11.616
Phosphorus (A)	2	1.816 ns	0.575*	1.19 *	112.803*
Potassium (B)	3	9.091*	0.619*	0.475*	155.026*
A x B	6	0.621 ns	0.458*	0.09 *	6.125*
Error	22	2.105	0.969	0.756	88.802

*Significant at 5% level
ns- Non significant