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Growth and Yield Performance of Maize (*Zea mays* L.) under Different Phosphorus Levels in Reddish Brown Earth Soil (Rhodustalfs) in Sri Lanka

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Abstract: Maize (Zea mays L.) is the second most important cereal crop after rice produced in Sri Lanka. The government of Sri Lanka has taken several steps to expand maize production in the country. A larger proportion of maize cultivation of the country is confined to the dry zone where Reddish Brown Earth (RBE) is the major great soil group in uplands. Reddish Brown Earth soils show high P adsorption capacity, hence availability of P to plant uptake is low. As such this study aimed to investigate growth and yield performance of maize under different P levels in RBE soils. The study was conducted as a pot experiment under greenhouse condition. Six different P levels [0, 20, 40, 80, 160 and 320 mg/kg of soil] were compared using two factor factorial in complete randomized design with seven replicates. Plant height, leaf area content, biomass content and yield parameters showed significant difference among tested treatments. Most of the tested parameters showed increasing trend with added P up to 80 mg/kg but negative relationship exhibited afterward. Treatment no. 4 (80 mg/kg of soil) recorded highest yield of 6.6 mt/ha. The study concludes that 80 mg P/kg soil is the most suitable phosphorus level for cultivating maize in RBE soil. However further field studies are needed to confirm the findings.

Introduction

Maize (*Zea mays* L.) is the second most important cereal crop grown in Sri Lanka. It is popular among Sri Lankan farmers due to the low cultivation cost. Maize is cultivated either as a rain fed or as a supplementary or fully irrigated crop mainly in dry zone of the country (Esham, 2014). In the last two decades, maize production has yielded compelling success with the introduction of hybrid seed that has significantly increased maize production in the country (FAOSTAT, 2014).

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Maize is mainly used for provender industry. In addition, Immature cob consumption also popular among all sectors of society today. Due to this high demand for green (immature) cobs, farmers tend to cultivate maize during off season even in nontraditional areas. It shows a great potential to increase maize production in the country and save foreign exchange which use to import maize products. Genetic improvement and expansion of the cultivated area with suitable management practices are two main ways of reaching higher production levels. Currently, Department of Agriculture of Sri Lanka has recommended to cultivate four open pollinated (OPV) and the one hybrid maize variety. In the recent years, exotic hybrid varieties have become popular among farmers. Uniform growth, ability to provide few extra grain per each ear harvested and high plant vigor due to increased metabolic activities are the attributes to this growing interest in hybrid maize among farmers (Karunarathna, 2001).

In spite of the increase in land areas under maize production, yield is still low. Some of the major causes of low maize yield are declining soil fertility and insufficient use of fertilizers resulting in severe nutrient depletion in soils. Maize requires adequate supply of nutrients particularly nitrogen, phosphorous and potassium for good growth and high yield (Liu *et al.*,2006).

Phosphorus (P) is a macronutrient that is essential for plant growth and crop production. Plants need P for growth throughout their life cycle, especially during the early stages of growth and development (Kettering, 2005). It controls mainly root development and the reproductive growth of plant (Wojnowska *et al*. 1995). Energy from photosynthesis and the metabolism of carbohydrates is stored in phosphate compounds for later use in growth and reproduction (Ayub *et al*. 2002).

Generally, P is the second most crop-limiting nutrient in most soils. The concentration of soluble phosphate in the soil solution is very low, and P is relatively immobile in the soil. Therefore, crop growth depends on the ability of replenishment of the soil solution from the other forms of P existing in the soil. The rate of replenishment, which determines the availability of P, is related to soil pH, P level in the soil, its fixation by the soil, and placement of added P (Brady and Weil 1999). A larger proportion of maize cultivation of the country is confined to the dry zone where Reddish Brown Earth (Rhodustalfs) is the major great soil group in uplands. Maize is widely grown in well drained and imperfectly drained RBE soils in both cultivation seasons. Reddissh Brown Earth soils show high P adsorption capacity, hence availability of P to plant uptake is low (Sanjeewani, *et al*.,2013). Therefore, P is one of the major deficient nutrients mainly in upland farming. Hence, response of the maize to added P fertilizer is a critical factor. As such this study aimed to investigate growth and yield performance of maize under different P levels in RBE soils in Dry zone, Sri Lanka.

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Materials and Methods

Location

This experiment was carried out in the Field Crop Research and Development Institute, Mahailupallama, Sri Lanka. The great soil group in the study area is Reddish Brown Earth (Rhodustalfs). The experimental site is located in the low country dry zone of Sri Lanka where altitude is 117 m above mean sea level. The mean annual rainfall is less than 1750 mm per year and the mean annual temperature is in the range of 25-30 ^{0}C.

Experimental Design

The study was conducted as a pot experiment under greenhouse condition. Six treatments were compared using two factor factorial in complete randomized design with seven replicates. Eighty-four pots which have 60 cm diameter and 65 cm height were arranged as illustrated in figure 01. Open pollinated variety (OPV) Ruwan and hybrid variety Pacific were tested under seven P levels. All the treatments were provided 325kgha^{-1} N and 50 kgha^{-1} K_2O as urea and muriate of potash respectively.

OPV - Ruwan

T6	T2	T1	T4	T3	T5	T4
T4	T6	T5	T3	T1	T2	T3
T5	T1	T2	T6	T4	T3	T6
T3	T5	T6	T1	T2	T4	T1
T1	T4	T3	T2	T5	T6	T2
T2	T3	T4	T5	T6	T1	T5
R1	R2	R3	R4	R5	R6	R7

Hybrid - Pacific

T6	T2	T1	T4	T3	T5	T4
T4	T6	T5	T3	T1	T2	T3
T5	T1	T2	T6	T4	T3	T6
T3	T5	T6	T1	T2	T4	T1
T1	T4	T3	T2	T5	T6	T2
T2	T3	T4	T5	T6	T1	T5
R1	R2	R3	R4	R5	R6	R7

Figure 01 – Field layout

Treatments

T1 – No P

T2 – 20mg P/kg soil

T3 – 40 mg P/kg soil

T4 – 80 mg P/kg soil

T5 – 160 mg P /kg soil

T6 – 320 mg P/kg soil

Pot Preparation and Crop Management

Eighty-four pots were prepared using black polythene (Diameter 60 cm and height 65 cm). Pots were filled with air-dried soil after mixing different level of P in the form of TSP. Then two seeds were planted in a pot with 2-3 cm depth. Thinning out were done 2 weeks after planting to manage single plant per pot. All the cultural practices were carried out according to Department of Agriculture recommendations. Cobs were harvested as final yield at maturity stage.

Soil and Plant Sampling and Preparation

Soil samples were obtained at the beginning of the pot experiment before adding treatments to measure initial soil parameters. The second sampling was done after harvesting to determine soil residual P contents in each and every treatment. Collected soil samples were air dried in a clean room at room temperature and passed through 2 mm sieve prior to analysis. Two plants were collected from each treatment at 5 weeks after planting. Collected samples were dried in an oven at 65 ^{0}C temperature and crushed using electrical chopper. Prepared plant samples were analyzed to determine total phosphorous content in plant tissues.

Table 01 – Standard methods used for soil analyses

Parameter	Analytical method
pH	soil: deionized water (1: 2.5) (Rhoades 1982)
Electrical conductivity	soil: deionized water (1: 5) (Rhoades 1982)
Organic carbon	Walkley–Black method. (Nelson and Sommer 1996)
Available nitrogen	Kjeldahl method (Bremner 1960)
Available phosphorous	Olsen extraction method followed by spectrophotometry. (Olsen and Sommers 1982)
Exchangeable potassium	Ammonium acetate extraction – Flame photometer method

Data Collection and Analysis

Prepared soil samples were analyzed for chemical parameters such as pH, Electric Conductivity (EC), available phosphorous, nitrogen, exchangeable potassium and organic matter content (Table 01). Plant height and leaf area were measured at 50% flowering stage. Seed dry weight, number of seeds per cobs, hundred seeds weight were measured as yield parameters. Plant biomass was taken at harvesting stage. Collected data were analyzed by the analysis of variance

(ANOVA) using SAS software package. Duncan's New Multiple Range test was used for mean separation of the treatment.

Results and Discussion

Soil properties at initial stage

The initial soil properties are shown in table 02. The mean soil pH was 6.4 indicating slightly acidic nature of soil reaction. The mean value of soil EC was 0.07 dS/m. Available N, P and exchangeable K contents were 8.7, 3.5 and 77.5 ppm respectively. It revealed that all these three nutrients were not sufficient for optimum growth. The initial soil OM content was 2.1%. The texture of the soil used to pot experiment was sandy clay loam.

Table 02: Soil properties at initial stage

Properties	Value
pH	6.4
EC	0.07 dS/m
Exchangeable potassium	77.5 ppm
Available phosphorous	3.5 ppm
Available nitrogen	8.7 ppm
Organic matter	2.1%
Soil texture	Sandy Clay Loam

Soil Available P at Harvesting

The variation of soil available P among tested treatments at harvesting is given in table 03. It indicates that soil P concentration was significantly affected by rates of added soil P. It has increased significantly with progressive increase in added soil P level; thus, the highest soil P concentration at harvesting was recorded in T6 treatment where highest P content (320 mg/kg) was added. However, no significant difference was observed in soil P levels in relation to tested varieties. The mean value of P of variety Pacific grown soil was somewhat lesser than the soil P of variety Ruwan indicating ability of higher P uptake of variety Pacific.

Plant Tissue Phosphorus

The plant P content was significantly different ($P<0.05$) among treatments (Table 03). It showed increasing trend with increasing of P added to the soil. The plant P content varied from 2.9 to 15.4 ppm. Treatment 6 recorded the highest P content of 15.4 ppm while the lowest plant tissue phosphorus level of 2.9 ppm was recorded in T1 treatment. However, no significant difference ($P>0.05$) of plant tissue P level was observed between two varieties.

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Table 03 – Soil available P and plant tissue P at harvesting

Treatment	Soil P (ppm)	Plant tissue P (ppm)
T1 – No P fertilizer	2.6 f	2.9 d
T2 – 20 P mg/kg	8.6 e	7.7 c
T3 – 40 P mg/kg	13.0 d	11.2 b
T4 – 80 P mg/Kg	16.7 c	13.6 ab
T5 – 160 P mg/kg	24.7 b	14.1ab
T6 – 320 P mg/kg	58.4 a	15.4 a
Variety		
Pacific	20.2 a	11.0 a
Ruwan	21.2 a	10.6 a
CV%	8.2	16.8

Means donated by same letter are not significantly different from each other at p<0.05, as determined by Duncan's multiple range tests

Plant Height at 50% Flowering Stage

Plant growth as reflected by plant height was significantly affected by P application. Results indicated that different levels of P had a significant effect ($P<0.05$) on plant height (Table 04). The highest plant height of 174 cm and the lowest plant height of 146 cm were reported in T4 and T1 treatments respectively. Plant height increased with the increasing of added P level up to 80 mg P/Kg of soil. This revealed that P at the rate of 80 kg /ha might be the optimum level. Therefore, further increase in P above 80 kg/ ha did not have a directly proportional effect on the plant height of maize. Similar response pattern of maize to added soil P was also observed by Arain *et al*. (1989). Increase of plant height against added P was probably due to better development of root system and nutrient absorption (Mandal *et al*. 1992; Tandon, 1992). Variety Pacific showed higher mean plant height (163.2 cm) compared to variety Ruwan which showed lower plant height of 154.1 cm at 50% flowering stage.

Table 04: Growth parameters

Treatment	Plant height (cm)	Pant leaf area (cm^2)	Biomass (g)
T1 – No P fertilizer	146.0 c	247.6 e	344 c
T2 – 20 P mg/kg	156.1 c	340.2 bc	420 b
T3 – 40 P mg/kg	157.0 b	351.3 b	440 b
T4 – 80 P mg/Kg	174.3 a	398.9 a	514 a
T5 – 160 P mg/kg	160.0 b	296.5 dc	430 b
T6 – 320 P mg/kg	158.7 b	275.8 de	414 b
Variety			
Pacific	163.2 a	278.9 b	483 a

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Ruwan	154.1 b	357.8 a	371 b
CV%	5.08	8.91	9.84

Means donated by same letter are not significantly different from each other at p<0.05, as determined by Duncan's multiple range tests

Plant Leaf Area and Biomass Content

Leaf area growth determines light interception and is an important parameter in determining plant productivity (Gifford *et al*., 1984; Koester *et al*., 2014). According to the statistical analysis, plant leaf area values were significantly different. Highest leaf area value of 398.9 cm^2 was reported in T4 while the lowest value of 247.6 cm^2 was observed in T1 treatment. Leaf area values have increased with added P content from 0 to 80 mg/kg but the response was negative afterwards. Similarly, two varieties were significantly difference in terms of plant leaf area content.

The biomass production of treatments has increased with increasing soil P content but only up to the rate of 80 mg P/kg of soil. Then it showed reducing trend against T5 and T6 treatments. The highest biomass content was recorded in T4 and the lowest biomass was recorded in T1 treatment. There was a significant difference of biomass content between two varieties as well. Variety Pacific showed higher biomass content compared to variety Ruwan. Zia *et al*. (1988) and Ahmad et al, (2013) also reported similar increasing and decreasing effect on plant biomass content against added phosphorous levels.

Number of Seeds per Cob

Number of seeds per cob has direct effect on the total grain yield of maize. A significant difference of seeds per cob was reported among tested treatments. The maximum number of seeds per cob (418) was given in T4 while the lowest number was reported in T6. A significant difference between two varieties was also observed with respect to number of seeds per cob. Variety Pacific showed higher number of seeds per cob when compared to that of variety Ruwan.

This increased number of seeds in the cob could be attributed to the optimum availability of P in T4 treatment which was associated with increased rapid growth and development, thus those pots which received optimum P produced more seeds per cob as compared to other treatments. Arain *et al*. (1989) reported that number of seeds per cobs of maize increased with increase in P application. In addition, our results are also in line with findings of Zia *et al*. (1998) and Ahmad *et al*, (2013) whose observed the similar increasing trend of grain number in a cob with increasing P content in the soil. Sharma and Sharma (1991) also reported that phosphorous fertilizer applications significantly affected the grains per cob.

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Table 05: Yield components

Treatment	No of seeds	Hundred grain weight (g)	Dry seed weight (t/ha)
T1 – No P fertilizer	253b	30.3b	4.3b
T2 – 20 P mg/kg	254b	31.3b	4.7b
T3 – 40 P mg/kg	261b	32.3b	4.9b
T4 – 80 P mg/Kg	418a	45.1a	6.6a
T5 – 160 P mg/kg	209b	25.9b	3.6b
T6 – 320 P mg/kg	164b	24.9b	2.8b
Variety			
Pacific	315a	34.1a	5.7a
Ruwan	204b	29.1a	3.1a
CV%	25.9	23.5	25

Means denoted by same letter is not significantly different from each other at $p<0.05$, as determined by Duncan's range tests

Hundred Grain Weight

Grain weight is an important yield component that helps a lot in the grain yield estimate. Hundred grain weight of different treatments and two varieties are shown in table 05. A significant difference ($p<0.05$) of hundred grain weight was observed among treatments. The maximum hundred grain weight of 45.1g was reported in T4 treatment while the minimum hundred grain weight of 24.9 g was given in T6 treatment.

Fareed (1996) and Hussain *et al*, (2006) also observed an increase in 1000-grain weight with increase in N and P application. Phosphorus being responsible for good root growth directly affected the thousand grain weight. However, no significant varietal difference was observed with respect to hundred grain weight. There was a trend of increasing hundred grain weight from T1 to T4 but it showed decreasing trend afterward.

Dry Seed Yield

There was a significant difference ($p<0.05$) in dry seed weight among treatments. Results revealed that, maximum grain yield (6.6 t/ha) was produced by the treatment T4 followed by T3 treatment (4.9 t/ha). The T6 treatment resulted in minimum grain yield of 2.8 t/ha (Table 04). Increasing P level above 80 mg/kg of soil might be excessive that had decreased the grain yield which indicated that applying P in maize above 80 mg/kg is uneconomical. The increase in grain yield due to P application was also reported in many previous studies (Khan *et al*. 2005; Sharma and Sharma, 1996). Providing of P in optimum level is associated with increased root growth due to which the plants explore more soil nutrients and moisture. Over application of P may also affect negatively on grain yield indicating lowest yield in T6 treatment which had P level of 320 mg/kg of soil. There was a significant varietal effect on dry seed weight as well. Variety Pacific was reported the highest weight of 5.7 t/ha compared to dry seed weight of 3.1 t/ha given by the variety Ruwan.

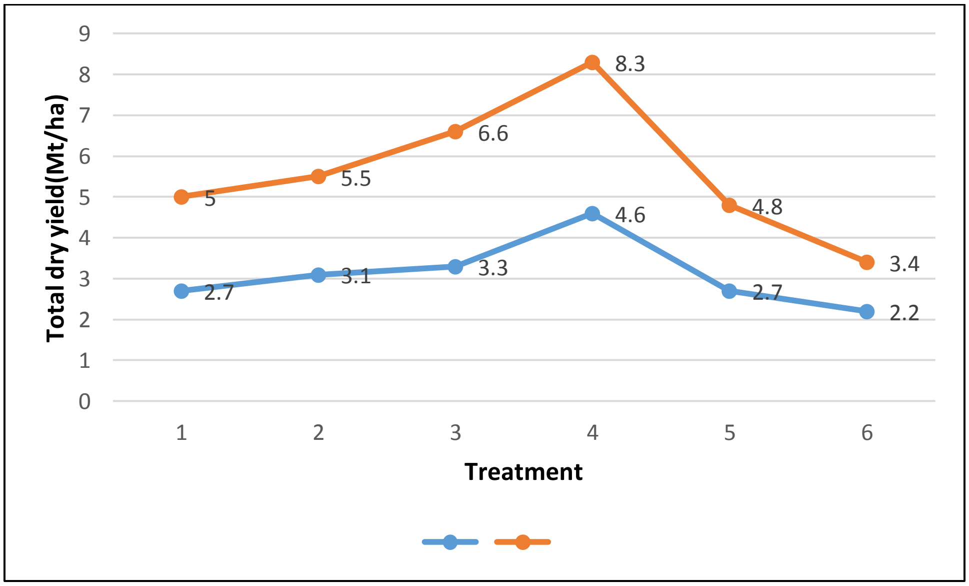

Figure 02: Effect of different treatment of dry seed yield

Conclusions

There was a positive response in maize to added phosphorus up to the level of 80 mg of phosphorus per kg of soil. However, the relationship was negative afterward indicating 80 mg/kg is the optimum phosphorus level for maize growing in Reddish Brown Earth soils. Further field studies are needed to confirm findings.

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