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IMPACT OF PHOSPHORUS LEVELS AND APPLICATION METHODS ON GROWTH, QUALITY AND QUANTITY OF BIOMASS PRODUCED BY FORAGE MAIZE

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ABSTRACT

Phosphorous (P_2O_5) is a primal component in crop nutrition but immobile in soil. Imbalanced use of phosphatic fertilizers with indecorous method of application reduces its efficiency in soil plant system. Therefore, a field experiment was conducted to examine the comparative efficacy of various levels of phosphorus and to sieve most site specific and appropriate application method for better quantity and quality of fodder produced by forage maize. Randomized Complete Block design (RCBD) with factorial arrangement in triplicate was used for this field experiment. Factors were; placement methods (broadcast and band placement) and phosphorus levels (40, 60 and 80 kg ha^{-1}). Placement methods exhibited a significant effect on green forage maize yield, fresh and dry weight, plant height, leaf area and stem diameter while non-significant effects on number of leaves $plant^{-1}$, crude fiber, and total ash, though the effects of phosphorus level were significant for all parameters. The highest green forage yield (58.15 t ha^{-1}) was achieved when phosphorus was applied as band placement. Similarly, maximal fresh (302.17 g) and dry weight per plant (78.83 g) of forage maize was also obtained when phosphorus was applied as band placement. Furthermore, phosphorus application as band placement gave greatest plant height (194.46 cm). Among yield and yield related components; highest leaf area per plant (2734.2 cm^{-2}) and also stem diameter (1.65), was found when phosphorus was applied as band placement. Quality traits including crude protein and crude fiber were also significantly affected by different phosphorus levels. Likewise, placement methods significantly affected the crude protein. In conclusion, P_2O_5 level of 80 kg per hectare applied with band method is better technique for significant improvement in yield and quality traits of forage maize.

Key words: Phosphorus, maize, application strategies, forage yield, crude protein,

INTRODUCTION

Maize (*Zea mays* L.) is a multi-dynamic crop which make available least expensive and heavy tonnage of fodder for livestock (Bello *et al*., 2010). Potential of forage maize is not being attained reasonably in Pakistan due to substandard method of cultivation, low plant population, imbalanced nutrient management, poor plant protection measures and lack of high yielding and disease resistant varieties. Among these factors, suboptimal crop nutrition is a primal factor in low biomass production and quality of feed.

Balanced and apposite plant nutrition improve forage production and quality (Mehmud *et al.*, 2003). Phosphatic fertilizers has now become indispensable for the balanced plant nutrition and sustainable crop yield as it increases fodder yield and quality by enhancing number of leaves on a plant, plant height, improved crude protein and ash contents (Cheema, 2000). It is essential for cell division and carbohydrate synthesis. It also helps in improving the quality and strengthens the plant against lodging. Among other primary nutrients, phosphorus is more limiting, and unlike other nutrients its deficiency retards overall plant growth and productivity and ultimately decreases the yield of crop (Raghothama and Karthikeyan, 2005). Meristematic tissues required phosphorous in huge amount, where cells division occurred rapidly (Brandy and Weil, 2002). So, it plays an important role in different physiological processes occurring in plants. All around the world efficiency of phosphorous is very low ranging from 10 to 25% (Afzal *et al*., 2005). Application of phosphorus is very essential for optimal crop growth, but unfortunately there is deficiency of this phosphorus in Pakistani soils (Vassilev and Vassileva, 2003). Moreover, after application of phosphoric fertilizer with improper methods, most of phosphorus remains unused in the soil.

Many methods of fertilizers application have been evolved with time having their own pros and cons. In general, localized banding placement of fertilizer in soil may enhanced fertilizer uptake efficiency than other methods of application (Nash *et al*., 2013). Broadcast application of P_2O_5 in the soil restricts the mobility. Sometime, banded application of phosphorus also struggles with phosphorus fixation and less amount of phosphorus fixed because less contact of phosphorus occurs with soil as compared to broadcast application (Weligama *et al*., 2008). Likewise, ammonium and phosphorus (P_2O_5) practiced by side-banded application method could enhanced significantly growth, nutrient uptake efficiency and productivity of maize which was accompanying by root proliferation due localized nutrient-induction (Ma et al.,2013). Localized concentration of nitrogen and phosphorous can establish a practically superlative root architecture with enhanced nutrient uptake efficiency (Shen *et al*., 2013). Higher wheat yield was attained with banded placement of NPK fertilizer (8–10 cm depth)than homogeneous fertilizer application. Therefore, band placement method of fertilizers application may enhance crop performance by enhancing nutrient use efficiency than broadcasting fertilizer. Less mobile nutrients like potassium or phosphorous applied as band placement method saturates soil solution in a small area within the root zone, which may decrease fixation of nutrients by soil particles (Trapeznikov *et al*., 2003). However, effects of band placement of fertilizer significantly varied with the alteration of depth at which fertilizer is placed. Every method of application for fertilizers has its own pros and cons. As, phosphorous is immobile in the soil, it becomes more important to explore the site specific application method and optimal level in enhancing the crop performance. Therefore, present field trial was executed to sieve the most effective P (P_2O_5) application method and optimal level for improved biomass production of forage maize and quality of feed for livestock.

MATERIALS AND METHODS

Experimental detail and planting material

Field experiment was conducted at Graduate Research Farm, University of Agriculture, Faisalabad (73^o East and latitude 31.40^o North Faisalabad, Pakistan) to examine the effects of different levels of phosphorus and its method of application on growth and yield aspects and also on quality of forage maize. Pre sowing composite soil samples was collected from the experimental field (sampling depth of 15 and 30 cm), and analyzed for physio-chemical analysis (Table. 1). The experiment was designed in field in randomized complete block design (RCBD) with factorial arrangements having three replications. Experiment was comprised of following treatments: factor A method of application (T_1: Broadcast and T_2: Band Placement), factor B phosphorus levels (kg ha^{-1}) P_1: 40, P_2: 60, P_3: 80. Net and gross plot size was 5 m x 1.8 m and 6m ×1.8m respectively. Seeds of Sarghoda-2002 cultivar were collected from Fodder section, Ayub Agricultural research institute, Faisalabad, Pakistan.

Crop husbandry

Crop was sown during 1st week of May, 2014 using seed rate 100 kg ha^{-1}. Pre- soaking irrigation (10 cm depth) was applied and then at "wattar" condition (workable moisture level), the field was tilled twice with a cultivator each followed by planking. Seed were planted in lines of 30 cm apart by utilizing single row hand drill. Recommended dose of nitrogen (140 kg ha $^{-1}$) was applied to all the experimental plots uniformly. Half of the nitrogen was practiced at sowing, while remaining n was applied with first irrigation. Nitrogen and phosphorus were applied in the form of urea and DAP respectively. All other agronomic practices (i.e. weeding, irrigation etc.) excluding those under study remained uniform for all the experimental plots. Harvesting was carried out at about 50 % flowering after 60 days of crop sown.

Measurements

Growth attributes measured were number of leaves, leaf area, stem diameter and plant height. Five plants were chosen and removed from each plot randomly before harvesting and growth parameters were recorded according to standard procedure. Dry matter yield per plot was obtained by multiplying the average dry weight per plant from each plot with the number of plant present in that plot and then the yield was converted into tons per hectare. All the plots of experimental units were harvested and the yield of each was determined with the help of field balance. After that the yield was converted into tons per hectare.

Crude protein (%)

AutoKjeldahl-370 apparatus was used to collect crude protein content. 1g of oven dried plant material, 30ml of concentrated H_2SO_4, and 5 g digestion mixture added and digested the material on the gas heater in Kjeldhal flask, cooled it and made volume upto 100 ml. For distillation 10 ml liquid was taken from this from this volume. Nitrogen which evolved as ammonia collected in a receiver containing mixed indicator (Bromocresol green and methyl red)and boric acid (2 %) solution and then titrated against standard (0.1 Normal)H_2SO_4. The reading obtained after titration against H_2SO_4 was then multiplied by 6.25 for protein determined.

Crude fiber (%)

2.0 g oven dried plant material in 500 ml beaker, added with 1.25% H_2SO_4 and distilled water to make the volume up to 200 ml. Then placed it on flame for 30 min, filtered and washed. Then again added 1.25% NaOH and distilled water to make the volume up to 200 ml. This was heated again, filtered and washed. Then sample was placed in crucible and it was kept in oven at 70°C for drying. When sample was dried, weight and placed the crucible on flame and ignited when smoke disappeared, it was placed in a muffle furnace and heated (600°C) till gray ash obtained. Then cooled material was weighted. The fiber percentage was calculated using the formula (AOAC, 2005):

$$\text{Crude fiber percentage} = \frac{\text{Weight of dried residue-weight of ash}}{\text{Weight of moisture free sample}}$$

Total ash (%)

A dried crucible was weighted (W_1) and 1.0 g of oven dried and well grinded sample was put in it. The crucible was placed in muffle furnace (600°C) till a grey ash was obtained. Residue then cooled in a desiccator and reweight (W_2) the ash percentage was calculated as described in AACC, (2000):

$$\text{Crude fiber percentage} = \frac{W_2 - W_1}{\text{Weight of sample}} \times 100$$

Statistical Analysis

Collected data was statistically evaluated with Fisher s analysis of variance method. Differences among treatment means were compared by employing least significance difference (LSD) test at 5 % probability level (Steel *et al*., 1997). Fluctuations in metrological parameters were also recorded during the whole season of the crop at metrological station of crop physiology to assess the weather influence under climatic scenario of Faisalabad (Figure. 1).

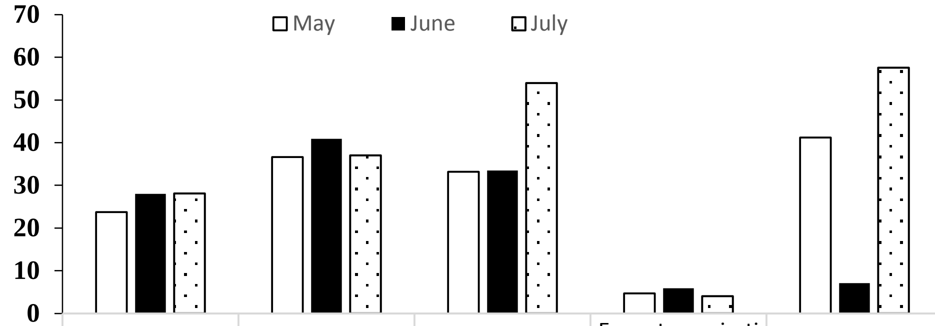
RESULT AND DISCUSSION

Stem diameter and plant height

Stem diameter and plant height are important growth traits which determine forage yield. There is a direct relation between forage yield and height of the plant so, it has a primal importance in the studies of green forage. Stem diameter and plant height were significantly affected by various levels of phosphorous. Highest stem diameter and plant height were observed in P_3 (80 kg ha^{-1}) treatment (Table. 2). Statistically it was at par with P_2 (60 kg ha^{-1}), while least stem diameter and plant height were recorded in P_1 (40 kg ha^{-1}) treatment. Increase in plant height and stem diameter with phosphorus application has also been reported in sorghum (Ayub *et al*., 1997).Among phosphorus application method highest plants (186.96 cm) were observed in band placement, while lowest plants (172.86 cm) were found in broadcast application (Table 2). Band method of application, which gave higher mean values for plant height and stem diametre had advantage over the broadcast method of Phosphorus application as band placement is more localized to roots which may help the plant to enhanced uptake of phosphorous and improved plant height and stem diameter (Mazengia, 2011).

Forage yield

More no. of leaves will contribute to more forage productivity. Significant variations were detected among different levels of phosphorus regarding number of total leaves per plant and leaf area. Largest leaves per plant and maximum leaf area were documented in case of 80 kg ha^{-1},while lowest values were observed when phosphorous was applied @ 40 kg ha^{-1}. Enhancement in total number of leaves per plant and leaf area with phosphorus application may be due to increase growth aspects of crop (Zahoor, 2014; Ali *et al*., 2002). Placement methods have non-significant effect on number of leaves per plant. Band placement method of phosphorous gave significantly better results than broadcast method as it is a preferable method for fertilizer P application to enhance leaf area per plant (Rehim*et al*, 2010). Attained results exhibits that, different levels of phosphorus significantly affected the green forage yield of maize than control (Table. 3). Highest quantity of green forage and dry matter yield was obtained in treatment where 80 kg phosphorous per hectare was used which was statistically at par (53.80 t ha^{-1}) with treatment of 60 kg P_2O_5 per hectare. Least green forage and dry matter yield is was obtained in case of those plots which were fertilized @ 40 kg P per hectare. The escalation in green forage and dry matter yield under P application can be credited to the improvement in all growth parameters examined in this experiment. Likewise, enhancement in in fodder yield with P application has also been elucidated by scientist's expressly Ayub *et al*. (1999), Ali, (2000), Cheema, (2000) and Husnain, (2001). Among application methods maximal green forage yield of maize (57.11 t ha $^{-1}$) was obtained in band placement while minimal green forage yield of maize (50.44 t ha $^{-1}$) was obtained in broadcast application method may be due improved availability of P (Gurmani *et al*., 2006; Imran et al., 2007). The interactive effects of various levels of P (P_2O_5) and placement method was non-significant.



	Min. Temp. (°C)	Max. Temp. (°C)	Average R.H. (%)	Evapotranspiration(mm)	Rainfall (mm)
May	23.7	36.6	33.2	4.7	41.2
June	28	40.9	33.5	5.9	7.1
July	28.1	37	53.9	4	57.5

Metrological data during the growing season of forage maize.

Fig. 1.Variations recorded in metrological data during growing season of forage maize.

Table 1. Chemical and organic properties of experimental site.

Characteristics	**Soil depth**	
	0-15 cm	15-30 cm
EC (d Sm^{-1})	1.88	1.99
pH$_s$	8.0	8.1
Potassium (ppm)	9.6	7.9
Phosphorus (ppm)	118	107
Organic Matter (%)	1.62	0.44
Saturation (%)	39	38
Textural Class : Sandy Loam		

Forage quality

Maize forage is most appropriate as it has high energy contents like protein and fiber contents than other cereal forages. Results from quality analysis of forage indicated that total ash, crude protein and fiber contents of forage maize are significantly affected by various levels of phosphorus applied to soil (Table. 3). Greatest values of total ash, crude protein and fiber contents were obtained in those experimental plots where P (P_2O_5) was practiced @ 80 kg per hectare followed by those plots where it applied @ 60 kg per hectare. These results were statically similar. Lowest total ash, crude protein and fiber contents were found in plots where 40 kg P per hectare was used. Improved contents of crude protein may be due to the enhanced early growth rate and improved nitrogen uptake by plants with higher level of P application. Nitrogen plays a vital role in the synthesis of protein. (Ayub *et al*., 2002; Husnain, 2001 and Cheema, 2000). Among P (P_2O_5) application methods highest crude protein contents (8.94 %) was obtained in case of band placement while least contents (8.06%) were obtained in broadcast application method. Localized band fertilization, had a positive effect on the initial growth of forage maize, as this method saturates the soil solution with nutrients especially slowly-mobile nutrients such as phosphorous and potassium in a relatively small area within the root zone, which can reduce fixation of nutrients by soil particles, and thus increasing nutrients availability (Farmaha *et al*., 2013). Therefore, it gave a greater amount of protein content than broadcast method of phosphorous application (Kruczek and Zulc, 2006). Non-significant difference among application strategies was attained for crude fiber and ash contents. Interaction between different levels of phosphorus and placement method was also non-significant for quality parameters.

Table 2. Effect of different P (P_2O_5) levels and application strategies on growth aspects of forage maize.

Treatments	**Plant height (cm)**	**Stem diameter (cm)**	**Total leaves ($Plant^{-1}$)**	**Leaf area (cm)**
P_1 (40 kg ha^{-1})	156.10b	1.23b	11c	2208.3b
P_2 (60 kg ha^{-1})	189.15a	1.46a	14b	2676.2a
P_3 (80 kg ha^{-1})	194.47a	1.65a	16a	2734.2a
LSD($p \leq 0.05$)	16.28	0.19	2.06	278.56
T_1 (Broad cast method)	172.86b	1.35b	13	2424.1b
T_2 (Banned Placement)	186.96a	1.54a	14	2655.0a
LSD($p \leq 0.05$)	13.29	0.16	Ns	227.44

Table 3. Effect of different P(P_2O_5)levels and application strategies on agronomic and quality aspects of forage maize.

Treatments	**Green forage yield (t ha-1)**	**Dry matter yield (t ha^{-1})**	**Crude protein (%)**	**Crude fiber (%)**	**Total Ash (%)**
P_1 (40 kg ha^{-1})	51.72b	12.00b	7.49b	27.21b	7.59b
P_2 (60 kg ha^{-1})	57.65a	16.16a	8.66a	32.85a	9.05a
P_3 (80 kg ha^{-1})	59.45a	17.83a	9.35a	34.11a	9.45a
LSD($p \leq 0.05$)	4.35	2.51	1.02	4.95	1.17
T_1(Broadcast method)	54.40b	14.22b	8.06b	30.45	8.49
T_2 (Banned Placement)	58.15a	16.44a	8.94a	32.32	8.90
LSD($p \leq 0.05$)	3.55	2.05	0.83	Ns	Ns

CONCLUSION

It is concluded that Phosphorous level of 80 kg ha^{-1} practiced with band placement method showed best performance than all the other treatments in increasing the biomass of forage maize and likewise, agronomic and quality related traits. Localized band placement, had a stimulating effect on the initial growth of maize and yield related aspects with significantly improved protein contents of forage maize.

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