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Effect of Phosphorus Biofertilizers on soil microbial population and growth characteristics of sweet corn (*Zea mays* L.)

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Abstract
A field experiment was carried out during *kharif*, 2018 on sandy clay loam soils of dry land farm of S. V. Agricultural College, Tirupati, Acharya, N. G. Ranga Agricultural University. The experiment was laid out in randomized block design with ten phosphorus management practices and replicated thrice. The soil microbial status was found to be significantly influenced by different levels and sources of phosphorus. Application of 100% RDPalong with AM @ 12.5 kg ha^{-1} and PSB@ 5 kg ha^{-1} (T_4) recorded significantly higher fungi and actinomycetes population in sweet corn. The maximum bacterial count was registered with 50% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_{10}), which was closely followed by that with 50% RDP + PSB @ 5 kg ha^{-1} (T_9). Among the different combinations of phosphorus sources tried, application of 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_4) recorded the maximum leaf area index and leaf area duration at all the stages of sweet corn.Combined application of 100% RDP + AM @ 12.5 kg ha^{-1}+ PSB @ 5 kg ha^{-1} to sweet corn is the most efficient integrated phosphorus management practice for better crop growth and soil microbial status.

Keywords: Phosphorus Biofertilizers, characteristics, *Zea mays* L.

Introduction

Maize (*Zea mays* L.) is a miracle crop and 3rd most important cereal next to rice and wheat. Maize is called as "Queen of Cereals" because of its productivity potential (22 t ha^{-1}) relative to any other cereal crop. The demand of maize plant for nitrogen and phosphorus is more than any other essential element for all the phases of development. It is absolutely necessary that essential nutrients should be supplied in appropriate proportion for reaping higher yields. Under the present trend of exploitive agriculture in India, inherent soil fertility can no longer be maintained on sustainable basis. Increasing awareness is being created on the use of organics including biofertilizers, which are the source of macro, secondary and micronutrients to sustain the soil fertility and productivity. Usage of phosphorus fertilizers along with a biofertilizer *i.e.* either phosphate solubilizer / mobiliser may find a solution to reduce the quantity of phosphatic fertilizer, which could be a more sustainable way of phosphorus management, by reducing chemical fixation and solubulizing the insoluble form of phosphorus.

Materials and Methods

The field experiment was conducted at S.V. Agricultural College Farm, Tirupati campus of Acharya N. G. Ranga Agricultural University in *kharif*, 2018. The soil of the experimental field was sandy clay loam in texture, with initial bacterial count of 17 X 10^6 CFU's g^{-1} of soil, fungal count of 3 X 10^4 CFU's g^{-1} of soiland actinomycetes count of 6 X 10^4 CFU's g^{-1} of soil. The field experiment was laid out in Randomized Block Design (RBD). There were ten treatments and three replications. The treatment details are furnished below:

T_1: 100% recommended dose of phosphorus (RDP)
T_2: 100% RDP + Arbuscular Mycorrhizae (AM)
T_3: 100% RDP + Phosphate solubilizing bacteria (PSB)
T_4: 100% RDP + AM + PSB
T_5: 75% RDP + AM
T_6: 75% RDP + PSB
T_7: 75% RDP + AM + PSB
T_8: 50% RDP + AM
T_9: 50% RDP + PSB
T_{10}: 50% RDP + AM + PSB

The recommended dose of fertilizer was 180-60-50 kg N, P_2O_5 and K_2O ha^{-1}. Phosphorus was applied as per the treatments while nitrogen and potassium was applied as common to all the treatments. Phosphate solubilizing bacteria (PSB) @ 5 kg ha^{-1} and Arbuscular Mycorrhizae (AM) @ 12.5 kg ha^{-1} were applied along with FYM at the time of sowing.

Pre and post harvest soil microbial count

The microbial population was estimated in the experimental soil collected before sowing and after harvesting of the crop. Soil samples were separately homogenized and used for microbial population estimation. The micro flora *viz*., bacteria, fungi and actinomycetes was estimated by serial 83 dilution plate count technique (Pramer and Schemidt, 1965) [1]. The plate was done on appropriate media (Nutrient agar for bacteria, Potato dextrose agar for fungi and Actinomycetes isolation agar for actinomycetes).

Leaf area index

Five plant samples were collected in each treatment outside the net plot area, leaving the extreme border row and the leaf area was taken at 20, 40, 60 DAS and at harvest, using Li-COR model, LI-3100 leaf area meter with electronic display and expressed in cm^2. Leaf area index was calculated by using the formula suggested by Watson (1952) [2].

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Unit land area}}$$

Leaf area duration (days)

Leaf area duration (LAD) expresses the magnitude and persistence of leaf area or leafiness during the period of crop growth. If leaf area is plotted against time, it produces a function that indicates the assimilatory capacity of a crop during the period in question (Watson, 1952) [2]. It represents the leafiness of the crop growing period. Thus unit of measurement of LAD may be in days or weeks or months.

$$\text{LAD} = \frac{(LA_1 + LA_2)\,(t_2 - t_1)}{2}$$

Results and Discussion

Bacteria: The maximum bacterial count was registered with 50% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_{10}), which was closely followed by that with 50% RDP + PSB @ 5 kg ha^{-1} (T_9) and 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_4) which maintained parity among them (Table 1 and Fig. 1). Increased dehydrogenase activity (DHA) at reduced doses of inorganic P fertilizer along with AM and PSB increases the carbon resources in rhizosphere soil, which is considered as the driving force for microbial activity and density as reported by Yang*et al.*(2013) [3]. Significantly lower soil bacterial population was recorded with 100% RDP (T_1).

Fungi

The highest fungal population was recorded with 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_4), which was closely followed by that with 50% RDP + AM @ 12.5 kg ha^{-1} (T_8). Application of 100% RDP (T_1) resulted in significantly lower fungal population. Among the different phosphorus management practices, application of AM had higher influence on fungi population. The probable reason might be due to the fact that fungal nature of applied biofertilizer and higher organic content of the soil that helped to increase the microflora. The present findings are in conformity with the results of Wahid *et al*. (2016) [4].

Actinomycetes

Application of 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_4) registered higher actinomycetes population(Table 1 and Fig. 1), which was closely followed by that with 75% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_7). The lowest actinomycetes population observed with 100% RDP (T_1) might be due to non supply of organic sources, which are the pre-requisite for microbial growth and development.

Table 1: Post - harvest soil microbial status as influenced by different phosphorus management practices

Treatments	Bacteria (No. × 10^6 CFU g^{-1})	Fungi (No. × 10^4 CFU g^{-1})	Actinomycetes (No. × 10^4 CFU g^{-1})
T_1 - 100% recommended dose of P_2O_5 (RDP)	66.7	16.0	22.3
T_2 - 100% RDP + AM @ 12.5 kg ha^{-1}	78.5	19.3	26.7
T_3 - 100% RDP + PSB @ 5 kg ha^{-1}	88.3	18.4	27.7
T_4 - 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	90.0	20.7	28.7
T_5 - 75% RDP + AM @ 12.5 kg ha^{-1}	79.3	19.3	26.3
T_6 - 75% RDP + PSB @ 5 kg ha^{-1}	87.3	18.0	26.2
T_7 - 75% RDP+ AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	88.0	19.7	28.0
T_8 - 50% RDP + AM @ 12.5 kg ha^{-1}	76.7	20.5	26.0
T_9 - 50% RDP + PSB @ 5 kg ha^{-1}	90.7	18.2	26.5
T_{10} - 50% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	91.2	19.8	27.2
SEm±	2.54	0.56	0.78
CD (P = 0.05)	5.2	1.6	2.3
Mean	83.6	18.9	26.5

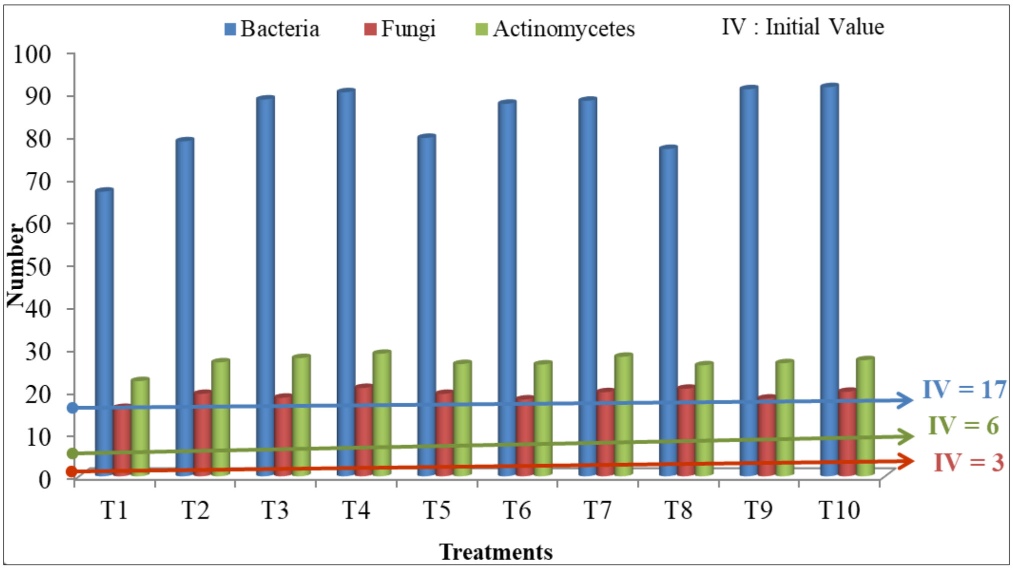

Fig 1: Post-harvest soil microbial status as influenced by different phosphorus management practices.

Leaf Area Index

Leaf area index of sweet corn tended to increase steadily with the age of the crop up to 60 DAS followed by slight decrease towards harvest irrespective of treatments due to senescence of lower leaves. Leaf area index at 40, 60 DAS and at harvest was significantly influenced by phosphorus management practices (Table 2 and Fig. 2). Among the different combinations of phosphorus sources tried, application of 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_4) recorded the maximum leaf area index at all the stages of sweet corn which was closely followed by 100% RDP + PSB @ 5 kg ha^{-1} (T_3). The lower value of leaf area index was recorded with 50% RDP + AM @ 12.5 kg ha^{-1} (T_8).

Taller plants usually provide better ventilated canopy and improves CO_2 exchange (Noova and Loomis, 1981) [5]. Increase in leaf area index with 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_4) could be due to availability of nutrients in adequate amounts resulting in sufficient formation of photosynthates which promote the metabolic activities, accelerated cell division and formation of meristematic tissues, number of functional leaves per plant increased, ultimately enhanced leaf area index. These results are in conformity with the findings of Singh *et al*. (2017) [6] and Yadav *et al*. (2015) [7].

Table 2: Leaf area index of sweet corn as influenced by different phosphorus management practices

Treatments	Leaf Area Index			
	20 DAS	40 DAS	60 DAS	At harvest
T_1 - 100% recommended dose of P_2O_5 (RDP)	0.25	2.50	4.45	4.18
T_2 - 100% RDP + Arbuscular Mycorrhizae (AM) @ 12.5 kg ha^{-1}	0.25	2.60	4.57	4.27
T_3 - 100% RDP + Phosphate solubilizing bacteria (PSB) @ 5 kg ha^{-1}	0.26	2.62	4.57	4.33
T_4 - 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	0.26	2.70	4.65	4.44
T_5 - 75% RDP + AM @ 12.5 kg ha^{-1}	0.24	2.42	4.39	4.13
T_6 - 75% RDP + PSB @ 5 kg ha^{-1}	0.25	2.45	4.40	4.17
T_7 - 75% RDP+ AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	0.26	2.56	4.53	4.20
T_8 - 50% RDP + AM @ 12.5 kg ha^{-1}	0.23	2.34	4.01	3.73
T_9 - 50% RDP + PSB @ 5 kg ha^{-1}	0.24	2.34	4.04	3.80
T_{10} - 50% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	0.24	2.38	4.14	3.87
SEm±	0.01	0.07	0.15	0.14
CD (P = 0.05)	NS	0.21	0.44	0.42
Mean	0.24	2.49	4.37	4.11

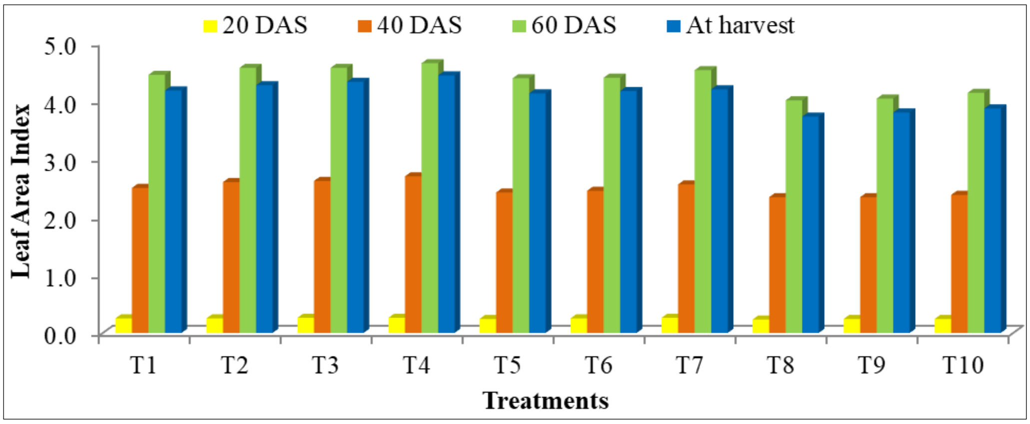

Fig 2: Leaf Area Index (LAI) of sweet corn at different growth stages as influenced by different phosphorus management practices.

Leaf Area Duration (LAD)

Leaf area duration of sweet corn showed an increasing trend with advancement of crop growth.Among the various combinations of phosphorus sources tried, application of 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_4) recorded maximum leaf area duration at all stages of sweet corn which was closely followed by 100% RDP + PSB @ 5 kg ha^{-1} (T_3) and 100% RDP + AM @ 12.5 kg ha^{-1} (T_2). (Table 3 and Fig. 3).The increase in LAD with increase in P probably may be due to P being the components of ATP might have contributed to a higher photosynthetic rate, abundant vegetative growth, assimilates formation and partitioning that resulted in more dry matter accumulation and leaf area $plant^{-1}$ (Lu and Barber[8], 1995).The lower value of leaf area duration at all stages of sweet corn was recorded with 50% RDP + AM @ 12.5 kg ha^{-1} (T_8).

Table 3: Leaf area durationof sweet corn as influenced by different phosphorus management practices

Treatments	Leaf area duration (days)		
	20 - 40 DAS	40 - 60 DAS	60 DAS - Harvest
T_1 - 100% recommended dose of P_2O_5 (RDP)	27.4	69.5	86.3
T_2 - 100% RDP + Arbuscular Mycorrhizae (AM) @ 12.5 kg ha^{-1}	28.5	71.7	88.3
T_3 - 100% RDP + Phosphate solubilizing bacteria (PSB) @ 5 kg ha^{-1}	28.8	71.9	89.0
T_4 - 100% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	29.6	73.5	90.9
T_5 - 75% RDP + AM @ 12.5 kg ha^{-1}	26.6	68.2	85.3
T_6 - 75% RDP + PSB @ 5 kg ha^{-1}	27.0	68.5	85.7
T_7 - 75% RDP+ AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	28.2	70.9	87.3
T_8 - 50% RDP + AM @ 12.5 kg ha^{-1}	25.7	63.5	77.4
T_9 - 50% RDP + PSB @ 5 kg ha^{-1}	25.7	63.8	78.4
T_{10} - 50% RDP + AM @ 12.5 kg ha^{-1} + PSB @ 5 kg ha^{-1}	26.2	65.2	80.0
SEm±	0.68	1.75	1.93
CD (P = 0.05)	2.0	5.2	5.7
Mean	27.4	68.7	84.9

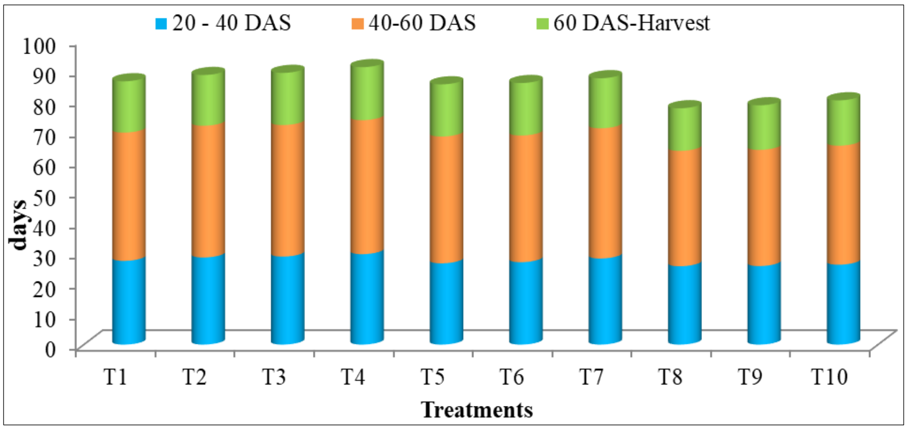

Fig 3: Leaf Area Duration (dm^{-2} day^{-1}) of sweet corn as influenced by different phosphorus management practices.

In conclusion, the present study indicated that combined application of 100% RDP + AM @ 12.5 kg ha^{-1}+ PSB @ 5 kg ha^{-1} to sweet corn is the most efficient integrated phosphorus management practice for better growth and soil microbial status. The higher plant growth rate was reflected from the better survival of lower leaves, resulting from prolonged nutrition, supplied through both inorganics and biofertilizers. Among the reduced phosphorus doses application of 75% RDP with AM @ 12.5 kg ha^{-1}andPSB @ 5 kg ha^{-1} was found to be biologically feasible and ecologically sustainable practice by maintaining the higher microbial population over sole application of 100% RDP. Long run adoption of fertilizers combined with microbial inoculants expected to increase the nutrient availability to the crop there by can exceed the sole fertilizer based production strategy.

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