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Evaluation of biofertilizers for phosphorus economy in 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. Plant height, Dry matter production and yield was significantly influenced by the different phosphorus management practices. Application of 100 % recommended dose of phosphorus along with Arbuscular mycorrhizae (AM) @ 12.5 kg/ha and Phosphate Solubilizing Bacteria (PSB) @ 5 kg/ha (T_4) recorded significantly taller plants, higher dry matter production, green cob (14033 kg/ha) and green fodder yield (17950 kg/ha) in sweet corn. However, 75 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha has given a remarkable green cob (13400 kg/ha) and green fodder yield (17210 kg/ha) along with a dry matter production which is in turn in parity with 100 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha (T_4) at 60 DAS and at harvest.

Keywords: Arbuscular mycorrhizae, biofertilizers, phosphorus, green cob yield, phosphate solubilizing bacteria and sweet corn

Introduction
Maize an important food and feed crop of the world, which is often referred to as 'Queen of cereals and miracle crop'. India is the seventh largest producer of maize with 28.72 million tonnes of production from 9.22 million hectares, with a productivity of 3.12 t/ha (USDA, December 2018). Being an exhaustive crop, it depletes approximately 24.3 kg N, 6.4 kg P and 18.3 kg K to produce one tonne of grain and its productivity, largely, depends on nutrient management system. 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. Phosphatic fertilizers are becoming costlier day by day and added to this recovery of phosphatic fertilizers is only 20-25 per cent mainly due to fixation of phosphates in soil. Thus the microbial inoculants are becoming more popular in India as these are inexpensive and easy to use with no side effects. 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
A field experiment was carried during *kharif*, 2018 at S. V. Agricultural College farm, Tirupati campus of Acharya N. G. Ranga Agricultural University, which is geographically situated at 13.5°N latitude and 79.5°E longitude, with an altitude of 182.9 m above the mean sea level in the Southern Agro-Climatic Zone of Andhra Pradesh. The soil of the experimental field was sandy clay loam in texture, with neutral pH (6.6), low in organic carbon (0.43 %) and available N (206.3 kg/ha), high in available phosphorus (60.0 kg/ha) and medium in available potassium (258 kg/ha).
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. 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 and Arbuscular Mycorrhizae (AM) @ 12.5 kg/ha were applied along with FYM at the time of sowing. Sweet corn cultivar Sugar -75 was tested in the present experiment. The crop was harvested on 3rd October, 2018.

Results and Discussion

Plant Height

Plant height at 40, 60 DAS and at harvest was significantly influenced by different phosphorus management practices (Table 1 and Fig. 1). Plant height of sweet corn tended to increase progressively with advancement of the crop up to maturity and the increase in plant height was rapid between 20 and 60 DAS, beyond which it was only marginal upto harvest. At all stages of observation application of 100 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha (T_4) resulted in taller plants, which was closely followed by 100 % RDP + PSB @ 5 kg/ha (T_3) and 100 % RDP + AM @ 12.5 kg/ha (T_2). The next best nutrient management practice in recording higher plant height was 75 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha (T_7). Highest plant height with 100 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha (T_4) might be due to optimum phosphorus fertilization along with both mobilizing and solubilizing microorganisms which might have triggered the plant nutrient uptake and there by the physiological activity. Similar results of increasing plant height by combined application of inorganic phosphorus with biofertilizers have been reported by Jinjala *et al.* (2016) and Kuniyal *et al.* (2012).

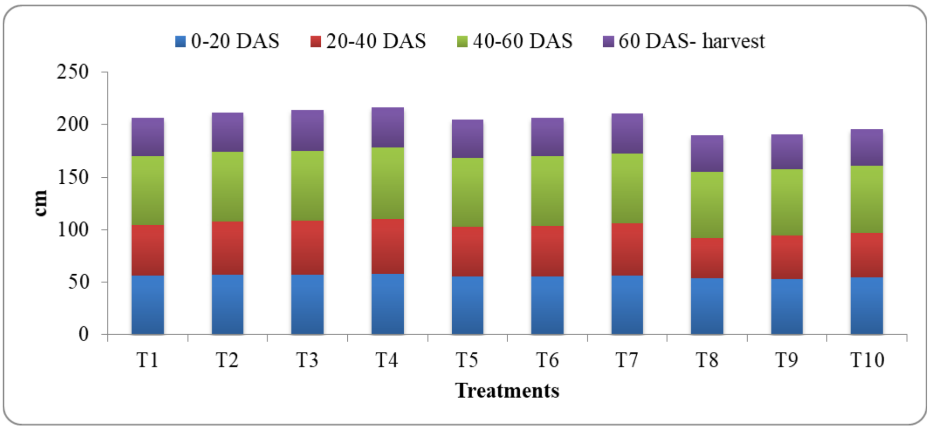

Fig 1: Plant height (cm) of sweet corn at different growth stages as influenced by different phosphorus management practices

Table 1: Plant height (cm) of sweet corn as influenced by different phosphorus management practices

Treatments	Plant height			
	20 DAS	40 DAS	60 DAS	At harvest
T_1 - 100 % recommended dose of P_2O_5 (RDP)	56.2	105	170	207
T_2 - 100 % RDP + Arbuscular Mycorrhizae (AM)	57.4	107	174	211
T_3 - 100 % RDP + Phosphate solubilizing bacteria (PSB)	57.0	109	175	214
T_4 - 100 % RDP + AM + PSB	58.0	110	179	216
T_5 - 75 % RDP + AM	55.5	103	169	205
T_6 - 75 % RDP + PSB	55.1	104	170	206
T_7 - 75 % RDP + AM + PSB	56.2	106	173	210
T_8 - 50 % RDP + AM	53.5	92	155	190
T_9 - 50 % RDP + PSB	53.0	94	157	191
T_{10} - 50 % RDP + AM + PSB	54.2	97	160	196
SEm±	1.66	3.0	4.9	5.9
CD (P = 0.05)	NS	9	15	18
Mean	55.6	102	168	205

Dry Matter Production

Dry matter production of sweet corn showed an increasing trend with the advancement of the crop (Table 2 and Fig 2).At all the stages of observation application of 100 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha (T_4) resulted in maximum dry matter, which was in turn on par with that of 100 % RDP + PSB @ 5 kg/ha (T_3) at 20 and 40 DAS. Continuous steady release of phosphorus through both inorganics and biofertilizers might have resulted in enhancing the carbohydrate metabolism and formation of starch and cellulose resulting in production of more dry matter. These findings are in confirmity with Hashim *et al.* (2015).The next best treatment in recording highest dry matter accrual was 100 % RDP + AM @ 12.5 kg/ha (T_2). The increase in total dry matter accumulation with increase in phosphorus probably may be due to phosphorus being the component of ATP might have contributed to a higher photosynthetic rate, abundant vegetative growth and assimilates formation and partitioning (Amanullah and Khalid, 2015).

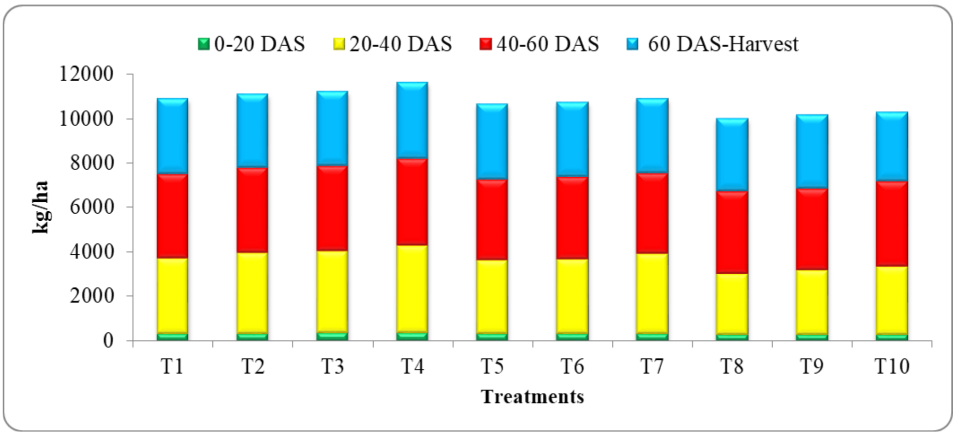

Fig 2: Dry matter production (kg/ha) of sweet corn at different growth stages as influenced by different phosphorus management practices

Table 2: Dry matter production (kg/ha) of sweet corn as influenced by different phosphorus management practices

Treatments	Dry matter production			
	20 DAS	40 DAS	60 DAS	At harvest
T_1 - 100 % recommended dose of P_2O_5 (RDP)	333	3734	7477	10888
T_2 - 100 % RDP + Arbuscular Mycorrhizae (AM)	343	3970	7758	11094
T_3 - 100 % RDP + Phosphate solubilizing bacteria (PSB)	357	4054	7846	11216
T_4 - 100 % RDP + AM + PSB	380	4299	8182	11610
T_5 - 75 % RDP + AM	312	3636	7268	10652
T_6 - 75 % RDP + PSB	326	3705	7362	10713
T_7 - 75 % RDP + AM + PSB	342	3926	7552	10903
T_8 - 50 % RDP + AM	275	3029	6706	10016
T_9 - 50 % RDP + PSB	287	3189	6852	10159
T_{10} - 50 % RDP + AM + PSB	300	3364	7165	10294
SEm±	9.4	106.5	219.6	310.9
CD (P = 0.05)	28	316	652	923
Mean	325	3691	7417	10754

Green Cob Yield

Conspicuous differences in green cob yield and green fodder yield of sweet corn was noticed due to different phosphorus management practices (Table 3 and Fig. 3). The highest green cob yield of sweet corn was with 100 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha (T_4) closely followed by 100 % RDP + PSB @ 5 kg/ha (T_3), which were at par and significantly superior to 50 % RDP + PSB @ 5 kg/ha (T_9) and 50 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha (T_{10}). Higher green cob yield might be attributed due to better growth parameters like plant height, leaf area index and dry matter production and yield attributing characters like number of kernels per cob, number of cobs per plant and cob weight. This is in accordance with the results reported by Jaliya *et al*. (2008).

Significantly higher green cob yield in treatments including AM and PSB could be attributed to build up of population of phosphate solubilising and mobilizing microorganisms in rhizosphere due to soil inoculation which increased the availability of phosphorus to plant through solubilisation effect and translocation of nutrient through network of hyphae in soil absorbing P from non rhizospheric zone and transport to plant roots (Hilda and Fraga, 1999).

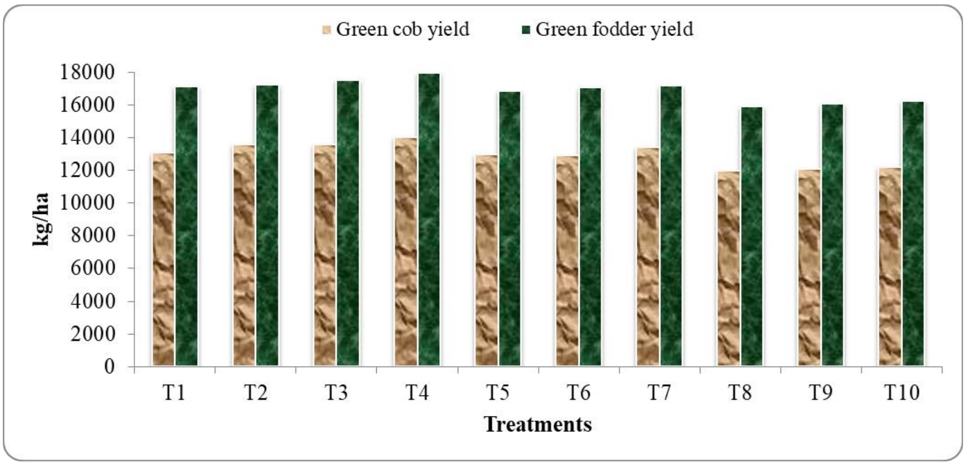

Fig 3: Green cob yield (kg/ha) and green fodder yield (kg/ha) of sweet corn as influenced by different phosphorus management practices.

Table 3: Green cob yield and green fodder yield (kg/ha) of sweet corn as influenced by different phosphorus management practices

Treatments	Green cob yield (kg/ha)	Green fodder yield (kg/ha)
T_1 - 100 % recommended dose of P_2O_5 (RDP)	13110	17143
T_2 - 100 % RDP + Arbuscular Mycorrhizae (AM)	13567	17266
T_3 - 100 % RDP + Phosphate solubilizing bacteria (PSB)	13603	17550
T_4 - 100 % RDP + AM + PSB	14033	17950
T_5 - 75 % RDP + AM	12967	16866
T_6 - 75 % RDP + PSB	12907	17086
T_7 - 75 % RDP + AM + PSB	13400	17210
T_8 - 50 % RDP + AM	11997	15896
T_9 - 50 % RDP + PSB	12107	16066
T_{10} - 50 % RDP + AM + PSB	12183	16233
SEm±	389.6	392.7
CD (P = 0.05)	1157	1167
Mean	12987	16926

Green Fodder Yield

Among the different phosphorus management practices, higher green fodder yield of sweet corn was recorded with 100 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha (T_4). Next best treatment was 100 % RDP + PSB @ 5 kg/ha (T_3). This might be due to relative higher level of phosphorus, probably increased mobility, absorption and translocation of nutrients leading to increased production of photosynthates by the crop resulting in increased biomass accumulation. Combined application of 100 % RDP and biofertilizers (T_4) enhanced the green fodder yield. This might be due to synergistic effect of AM and PSB which influenced SSP solubility and stimulated maize roots to absorb nutrients from soil and thus accelerated the photosynthetic rate, adequate biomass production that reflected on green fodder yield. The present results were in close conformity with the findings of Minaxi *et al*. (2013) and Kang *et al*. (2012).

In conclusion, the present study indicated that combined application of 100 % RDP + AM @ 12.5 kg/ha + PSB @ 5 kg/ha to sweet corn is the most efficient integrated phosphorus management practice for better growth, yield and economics Among the reduced phosphorus doses application of 75 % RDP with AM @ 12.5 kg/ha and PSB @ 5 kg/ha was found to be economically feasible and ecologically sustainable practice over sole application of 100 % RDP. Hence, application of 75 % recommended dose of phosphorus in combination with biofertilizers will safeguard the desire for higher crop productivity and economic returns by reducing the inorganic phosphorus requirement up to 25 per cent in sweet corn. Long run adoption of combined use of fertilizers along with biofertilizers expected to match and even exceed the sole fertilizer based production strategy.

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