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Evaluation of phosphorus substitution with VAM and phosphobacteria for sustainable production of Sugarcane

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Abstract
A field experiment was conducted by substituting the recommended dose of phosphorus from 25-50% to sugarcane plant crop with VAM and PB alone and combination of both and was evaluated with 100%, 75% and 50% of recommended dose of Phosphorus in eight treatments which were replicated thrice in RBD design. The variety of sugarcane used was 99V 30. The treatments includes T_1 - 100% P; T_2 - 75% P; T_3 - 50% P; T_4 - 50% P + VAM @5kg/ha + PB@8kg/ha; T5 - 75% P + VAM @5kg/ha; T_6 - 50% P + VAM @5kg/ha; T_7 - 75% P + PB@8kg/ha and T_8 - 50% P + PB @8kg/ha. Yield parameters, cane yield, commercial cane sugar yield, nutrient uptake of nitrogen and phosphorus and phosphorus availability in post-harvest soils by sugarcane plant crop were more with T_1 (100% recommended dose of phosphorus) and were on par with T_4 where 50% recommended Phosphorus and 50% was substituted with combination of VAM @5kg/ha + PB @8kg/ha.

Keywords: VAM, phosphobacteria, phosphorus substitution, sustainable production, sugarcane yield, juice sucrose, CCS yield, nutrient uptake and soil nutrient availability

Introduction
Indiscriminate use of chemical fertilizers without organics to the soil in the current years may result in spoiling of soil health. Substitution of chemical fertilizers with organic fertilizers helps in improving the soil fertility and productivity thereby which results in sustainability of soil besides reducing cost of cultivation. Growing sugarcane only with the application of high analysis inorganic fertilizers over a period of time resulted in deterioration of soil quality and productivity. Adverse effect of chemical fertilizers on the ecosystem is also increasingly felt. This could be mitigated by appropriately combining chemical fertilizers with other source of nutrients. Some quantity of applied chemical fertilizers only used by plants and some quantity lost in different ways. Phosphorus is highly immobile in soil and so losses are mostly in the form of fixation of P with other compounds depending upon pH of the soil unlike nitrogen which losses are mostly in the form of leaching, volatalisation and denitrification. Therefore it is necessary to reduce the use of chemical phosphatic fertilisers and to increase the use of phosphatic bio-fertilisers (VAM and Phosphobacteria) which make the use of fixed form of phosphorus by means of solubilisation and mobilization. Keeping in view of all these factors, this investigation was taken up with an objective to study the effect of VAM and phosphobacteria in combination with inorganic phosphorus on sugarcane yield and juice quality in plant crop.

Methods and Materials
A field experiment was conducted in sugarcane plant crop using the variety 99 V 30 at Sugarcane Research Station, Vuyyuru, Krishna district of Andhra Pradesh. The experiment was conducted in soil having pH 7.75 and EC 0.45 dsm^{-1} (Table 1). Soil is medium in available nitrogen (393 kg/ha) high in phosphorus (37 kg/ha) and potassium (430 kg/ha). Recommended doses of inorganic phosphorus was substituted with VAM and phosphobacteria from 25-50% either in alone or in combination in eight treatments *viz*., - T_1 - 100% P; T_2 - 75% P; T_3 - 50% P; T_4 - 50% P + VAM @5kg/ha + PB@8kg/ha; T5 - 75% P + VAM @5kg/ha; T_6 - 50% P + VAM @5kg/ha; T_7 - 75% P + PB@8kg/ha and T_8 - 50% P + PB @8kg/ha. Treatments were replicated thrice in R.B.D design.
Data was collected on shoot population at different stages of crop growth, cane yield and juice quality. Whole cane plant samples were collected at grand growth period, cut into pieces,

oven dried, powdered and analysed for nutrient contents of N, P & K using standard methods (Bremner and Mulvaney, 1982; Jackson, 1973 and Muhr *et al.,* 1963, respectively) [1, 2, 6]. Uptake of nutrients was calculated using the following formula…

$$\text{Uptake of nutrient (kg/ha)} = \frac{\text{\% Conc. of nutrient X Cane yield (t/ha)}}{100} \text{ X1000}$$

Soil samples were collected after harvest of crop and were analysed for pH & EC in 1:2 ratio, available nitrogen using alkaline potassium permanganate method (Subbiah & Asija, 1956) [9], phosphorus using Olsen's method (Watanabe and Olsen, 1965) [10], and potassium using neutral normal ammonium acetate method (Muhr *et al*., 1963) [6]. All the data was statistically analysed using method described by Panse and Sukatme (1978) [8].

Table 1: Initial soil analysis results in which experiment was conducted

S. No.	Parameter	Value
1	pH	7.75
2	E.C.	0.45 dSm^{-1}
3	Available nitrogen	393 $kgha^{-1}$
4	Available phosphorus	37 $kgha^{-1}$
5	Available potassium	430 $kgha^{-1}$

Results and Discussion

Data presented in Table - 2 indicates that 100% recommended dose of phosphorus (T1) and 50% P + VAM @5 kg/ha + Phosphobacteria @8 kg/ha (T4) recorded highest and on par shoot population at 90 and 120 days after planting. Cane yield and CCS yield were more with T1 (100% recommended dose of phosphorus) and was on par with T4 (50% P + VAM @5 kg/ha + Phosphobacteria @8 kg/ha). Vesicular- arbuscular mycorrhiza inoculation in combination with phosphorus increased dry and fresh shoot weight, leaf area and leaf number of strawberry compared to application of phosphorus alone. VA-fungi are associated with improved growth of many plant species due to increased nutrients uptake, production of growth promoting substances and synergistic interaction with other beneficial soil microorganisms such as N-fixers and P-solubilizer (Khanizadeh *et al.,* 1995) [3]. Quality of the juice *i.e.* juice sucrose percentage and CCS percentage were also more with the application of 100% of recommended dose of phosphorus (17.25 and 12.59% respectively) and was on par with the 50% substitution of phosphorus with VAM and phosphobacteria (16.92 and 12.36% respectively).

Highest nutrient uptake of nitrogen and phosphorus by sugarcane plant crop was recorded with T_1 where 100% P was applied through inorganic phosphorous and was on par with T_4 where 50% P was substituted with the combination of VAM @5kg/ha and Phosphobacteria @8kg/ha (Table-3). Non-significant results were obtained in potassium uptake. The enhanced effect of VA-fungi on the uptake of nutrient uptake might be attributed to two situations. In the first one is mycorrhizal hyphae act as extension to plant root, increasing root surface area and exploring larger soil volume, which will increase the chance of more nutrient uptake. Mycorrhizal association with plant root may also enhance translocation between root and shoot of the infected plant, hence enhancing the plant growth (Osonubi *et al.,* 1991) [7]. Besides, phosphobacteria helps in solubilisation of phosphorus and hence, the combination of VAM and phosphobacteria might have helped in better uptake of nutrients with increased pool of availability of nutrients. Kwapata and Hall (1985) [5] stated that symbiotic association of plant roots with VA-fungi often result in enhanced growth because of increased acquisition of phosphorus (P) and other low mobile mineral nutrients.

Table 2: Effect of VAM and phosphobacteria on yield and quality of sugarcane

Treatments	Shoot population ('000 /ha)				Cane yield (t/ha)	Juice sucrose (%)	CCS%	CCS yield (t/ha)
	90 DAP	120 DAP	180 DAP	240 DAP				
T1: 100% P	70.31	81.18	68.55	63.61	114.2	17.25	12.59	14.38
T2: 75% P	59.96	78.71	63.41	56.57	71.03	15.71	11.81	8.38
T3: 50% P	56.44	75.13	61.00	56.05	60.94	14.82	9.91	6.04
T_4: 50% P + VAM @ 5 kg/ha + PB @8 kg/ha	68.68	80.73	68.16	59.96	99.96	16.92	12.36	12.35
T_5:75% P + VAM@5kg/ha	63.93	81.12	65.75	59.57	82.04	16.41	12.04	9.90
T_6:50% P + VAM@5g/ha	57.81	80.01	62.95	57.29	74.09	15.71	11.00	8.15
T_7:75% P + PB @8 kg/ha	75.58	80.27	67.97	63.34	93.52	16.87	11.89	11.12
T_8:50% P + PB @8 Kg/ha	61.91	79.29	63.61	57.29	76.43	15.88	10.89	8.32
C.D @5%	10.24	NS	NS	4.84	15.52	1.003	1.13	2.08
C.V (%)	9.1	5.4	5.9	4.7	10.6	3.5	5.6	12.1

Table 3: Effect of on VAM and phosphobacteria on nutrient uptake by sugarcane

Treatments	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
T1: 100% P	385.77	109.87	633.22
T2: 75% P	248.44	59.29	356.99
T3: 50% P	200.96	55.52	355.75
T_4: 50% + VAM @5 kg/ha + PB @8 kg/ha	371.36	89.64	615.85
T_5:75% P + VAM@5 kg/ha	330.30	76.37	444.88
T_6:50% P + VAM@5 g/ha	300.66	66.43	469.62
T_7:75% P + PB @8 kg/ha	334.36	93.05	568.05
T_8:50% P + PB @8 Kg/ha	299.76	70.77	471.78
C.D @5%	86.43	22.478	NS
C.V (%)	16	16.5	32.9

Nutrient availability of soil after harvest of Sugarcane plant crop (Table-4) except phosphorus. Nutrient availability of phosphorus in post-harvest soils was more with T_4 where 50% of phosphorus was substituted with VAM and Phosphobacteria and was on par with 100% phosphorus application (T_1). Non-significant results were obtained with the other nutrients such as nitrogen and potassium. The mobilization of P from soil to the plants is mediated by hairy root systems of the mycorrhizal fungi through plant roots. It commonly infect plant roots, including those of sugarcane forming beneficial symbiotic relationships (Kelly *et al*., 1997) [4].

Table 4: Effect of VAM and phosphobacteria on nutrient availability of soil after harvest of sugarcane crop

Treatments	pH	E.C. (dS/m)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
T1: 100% P	7.88	0.52	264.67	78.56	574.77
T2: 75% P	7.93	0.43	243.33	46.48	533.47
T3: 50% P	7.90	0.51	252.67	38.18	472.11
T_4:50% + VAM@5kg/ha + PB@8kg/ha	7.85	0.49	279.33	86.22	343.14
T_5:75% P + VAM@5kg/ha	7.95	0.53	273.67	66.32	272.83
T_6:50% P + VAM@5g/ha	7.92	0.49	271.33	58.72	828.34
T_7:75% P + PB @8 kg/ha	7.96	0.47	258.33	71.64	650.85
T_8:50% P + PB @8 Kg/ha	7.88	0.53	264.33	61.16	569.62
C.D @5%	NS	NS	NS	8.50	NS
C.V (%)	0.5	15.1	6.8	9.20	48.8

Conclusion

Highest cane yield, commercial cane sugar yield, juice quality and nutrient uptake were obtained with 100% of recommended dose of phosphorus and was on par with the application of 50% of recommended phosphorus along with VAM @5 kg/ha and phosphobacteria @8 kg/ha. Hence, it can be concluded that 50% of recommended dose of phosphorus can be substituted with combination of VAM @5 kg/ha and phosphobacteria @8 kg/ha without reduction in yield and quality of sugarcane.

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