International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(4): 3626-3630

Received: 19-07-2020
Accepted: 05-08-2020

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Studies on effect of phosphorus levels, time of it's application along with arbuscular mycorrhiza on yield, quality and phosphorus use efficiency in sugarcane

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DOI: https://doi.org/10.22271/chemi.2020.v8.i4at.10210

Abstract
A field experiment was conducted in clayey textured soil at N.M. College of Agriculture, Research farm, Navsari Agril., University, Navsari, Gujarat during 2017-18 and 2018-19 with the view to evaluate an appropriate phosphorus level (100 and 75% of RD of P_2O_5), determining the time of P_2O_5 application (Basal and 50-50% Split), with and without use of biofertilizer as arbuscular mycorrhiza (AM) on the yield, quality and Phosphorus use efficiency (PUE) of sugarcane. The pooled data of two seasons indicated that sugarcane crop responded significantly with phosphorus management. Significantly highest yield attributes, cane, green top and quality of juice were recorded with 100 percent RD of P_2O_5, splitting of phosphorus and with the use of AM in Sugarcane. Similar significant results in terms of P content in juice and sugar yield were recorded. The Agronomic phosphorus use efficiency and partial factor productivity were enhanced significantly with splitting of P_2O_5 and AM in sugarcane.

Keywords: Phosphorus levels, Split application of phosphorus, Agronomic efficiency, Partial factor productivity, AM

Introduction

Sugarcane plays a major role in the economic development of sugarcane growing areas of the country and hence, enhancing sugarcane production will definitely help in the socio-economy prosperity of the farmers and other stakeholders associated with sugarcane cultivation.In Gujarat, during 2017-18, total cane production was 120.52 lakh tonnes from an area of 1.82 lakh hectares with average productivity of 66.22 tonnes/ha. Total sugar production was recorded at about 10.67 lakh tonnes and 10.19 percent sugar recovery Anonymous (2019) [2]. Sugarcane is an important cash crop of South Gujarat and as such most of the sugarcane growers depend upon it for their cash requirements. Hence, adequate net profit is important so that they stick up and continue sugarcane farming. The crop is heavy feeder of plant nutrients and removes about 1.2 kg N, 0.6 kg of P_2O_5 and 3.4 kg K_2O tonne of cane of production Singh (2000) [13].

Phosphorus plays a pivotal structure and regulatory role at the nexus of photosynthesis, root development, energy conversation and transformations, carbon metabolism, redox reactions, enzyme activation/ inactivation, signalling and nucleic acid synthesis. About 98 percent of soils have an inadequate supply of available phosphorus and likely to induce a deficiency of this mineral. Phosphorus fertilizers are relatively costly and are not used by the farmers in adequate amounts resulting in to stagnation or decline in sugarcane productivity over the years. However, P efficiency can be improved by enhancing internal utilization efficiency with the use of microbial inoculants Richardson *et al.* (2011) [12]. The symbiotic association formed by fungi with roots of higher plant is known as mycorrhiza, are of particular importance in the uptake of phosphorus and some micronutrients thus enhancing the beneficial microbial populations in the root zone.This necessitates the judicious use of P fertilizers by way of increasing their use efficiency by different phosphorus levels it's application methods along with biofertilizers. This will not only economize on the cultivation of sugarcane, but will also narrow down the gap between nutrient requirement and production, which is around 8-10 Mt/yr.

Considering these facts, the present investigation was conducted to find out the optimum levels, and their time of application along with arbuscular mycorrhiza (AM) for sugarcane crop in South Gujarat condition.

Material and Methods

Field experiments were conducted at N. M. College of Agriculture Navsari, Agril. University, Navsari, Gujarat during 2017-18 and 2018-19 seasons on different block of Agronomy farm. The soil of the experimental field was Inceptisols comprising member of fine, montmorillonitic isohyperthermic family of *Vertic Ustrochrepts*, clayey in texture having pH slightly alkaline, normal in conductance, low in soil available nitrogen and phosphorus and medium in potash. Three main experimental factors consisting each of two levels comprising A. Phosphorus levels; A_1- 100 percent recommended dose (RD) of P_2O_5 and A_2- 75 RD of P_2O_5, B. Time of phosphorus application as; B_1- 100 percent of P_2O_5 (100% as basal dose) application and B_2-50 percent of P_2O_5 as basal dose + 50 percent P_2O_5 at final earthing up (50-50% splitting) and C. Application of AM as; C_1=No application of AM and C_2= Application of AM were replicated in four replication in a randomized block design (Factorial) with gross plot size 6.3 x 6 m^2 (0.9 m row size). Control plot was kept outside the experimental unit to calculate agronomic use efficiency. Except P_2O_5 as a chemical fertilizer and AM; control plot was fertilized with RD of N and K_2O/ha. The variety used was CoN 05071 was planted with two eye bud setts @ 50000/ha. The experiments were planted in the month of December and harvested at peak maturity in both the seasons. The RD of chemical fertilizer was 250 N: 125 P_2O_5: 125 K_2O kg/ha and biofertilizer AM (arbuscular mycorrhiza) (*Glomus intraradis*) containing 3000 IP/g was applied in sugarcane @ 250g /ha at the time of planting + 200 g /ha at the time of final earthing up. Nitrogen was applied @ 250 kg/ha in the form of urea in all treatments in four splits, 15 percent at the time of planting, 30 percent at 45 DAP, 20 percent at 90 DAP, and 35 percent at 120 DAP (Before final earthing up) P_2O_5 was applied @ 125 kg/ha and 93.25 kg/ha in the form of super phosphate as per treatment and common dose of K_2O @125 kg K_2O/ha in the form of muriate of potash were applied at the time of planting. Common field management practices were followed for all the treatments. Data was collected on NMC/ha, average cane weight, DMY yield of cane and trash, millable cane yield, green top yield, juice quality and P use efficiency of sugarcane. Five plants were selected randomly from net plot for recording the yield attributes and juice quality parameters. The Sucrose (%), Commercial cane sugar (CCS%), pol percent in cane, purity percent and commercial cane sugar yield (CCS t/ha) were calculated by Anonymous (1970) [1]. The Phosphorus content in juice was estimated by Dil. HCl method, Brown and Zerban (1941) [3]. Further P uptake was calculated by using formula.

$$Nutrient\ uptake\ (kg/ha) = \frac{Content\ in\ plant\ (\%)\ x\ Dry\ matter\ yield\ (kg/ha)}{100} \quad (1)$$

The estimated value of agronomic efficiency (AE), partial factor productivity (PFP) and recover efficiency (RE) of applied P were computed using the following expressions in the equation 2 to 4.

$$AE = \frac{Cane\ yield_F(kg/ha) - Cane\ yield_C\ (kg/ha)}{Quantity\ of\ nutrient\ applied\ (kg/ha)} \quad (2)$$

Paul *et al*. (2014) [11].

Where F= Fertilized plot, C= Control plot

$$PFP_{(P)} kg/kg = \frac{Cane\ yield\ (kg/ha)}{Amount\ of\ phosphorus\ applied\ (kg/ha)} \quad (3)$$

Cassman *et al.* (1996) [4].

Phosphorus use efficiency is measured by the “Balance Method”- P removed in crop expressed as a percentage of P applied.

$$Phosphorus\ recovery\ (\%) = \frac{Phosphorus\ removal\ by\ crop}{Phosphorus\ applied} x\ 100 \quad (4)$$

Syers *et al.* (2008) [14]

The statistical analysis of data recorded for various characters studied in the investigation was followed by using statistical procedures appropriate to Factorial Block Design as described by Panse and Sukhatme (1978) [10] and the significance was tested by "Variance ratio" i.e. “F” test. Five percent level of significance was used to test the significance of results.

Table 1: Yield attributing parameters and yield of sugarcane influenced by phosphorus management in sugarcane

Treatments	Number of millable cane per hectare	Average cane weight (kg)	DMY (kg/ha)		Millable cane yield (t/ha)	Green top yield (t/ha)
			Cane	Trash		
Phosphorus levels (A)						
A_1:100% RD of P_2O_5	88052	1.102	21870	7914	89.77	21.76
A_2: 75% RD of P_2O_5	80657	0.971	15961	6448	81.32	17.77
SE m ±	1554	0.019	536	157	1.85	0.45
CD at 5%	4434	0.054	1530	448	5.27	1.27
Time of phosphorus application (B)						
B_1: 100% P_2O_5 at planting	80594	0.997	17322	6663	79.57	18.07
B_2: 50% P_2O_5 at planting + 50% P_2O_5 at final earthing up	88115	1.077	20510	7698	91.52	21.46
SE m ±	1554	0.019	536	157	1.85	0.45
CD at 5%	4434	0.054	1530	448	5.27	1.27
Application of arbuscular mycorrhiza (C)						
C_1: No AM	78879	0.974	15576	6801	77.53	17.46
C_2: AM	89829	1.099	20256	7561	93.56	22.07
SE m ±	1554	0.019	536	157	1.85	0.45
CD at 5%	4434	0.054	1529	448	5.27	1.27
Significant interactions	B x C	--	B x C	B x C	B x C	B x C
C.V.%	10.4	10.3	16.0	12.4	12.2	12.74
Control (No P_2O_5 application)	--	--	12866	5082	60.1	14.1

Table 2: Sugarcane juice quality parameters influenced by phosphorus management

Treatments	Sucrose %	CCS %	Pol% in cane	Purity %	P content (mg/l)	CCS yield (t/ha)
Phosphorus levels (A)						
A_1:100% RD of P_2O_5	18.67	13.23	14.04	93.04	536.1	11.88
A_2: 75% RD of P_2O_5	18.47	13.08	13.88	93.01	510.5	10.65
SE m ±	0.12	0.09	0.09	0.09	3.7	0.25
CD at 5%	NS	NS	NS	NS	10.6	0.72
Time of phosphorus application (B)						
B_1: 100% P_2O_5 at planting	18.46	13.08	13.87	93.03	516.5	10.40
B_2: 50% P_2O_5 at planting + 50% P_2O_5 at final earthing up	18.68	13.23	14.05	93.02	530.1	12.13
SE m ±	0.12	0.09	0.09	0.09	3.7	0.25
CD at 5%	NS	NS	NS	NS	10.6	0.72
Application of arbuscular mycorrhiza (C)						
C_1: No AM	18.50	13.09	13.89	92.82	514.2	10.16
C_2: AM	18.65	13.22	14.02	93.23	532.4	12.37
SE m ±	0.12	0.09	0.09	0.09	3.7	0.25
CD at 5%	NS	NS	NS	0.23	10.6	0.72
Significant interactions	--	--	--	--	--	B x C
C.V.%	3.7	3.9	3.7	0.6	6.3	12.7

Table 3: Phosphorus uptake and phosphorus use efficiency influenced by phosphorus management in sugarcane

Treatments	P uptake (kg/ha)		Agronomic phosphorus use efficiency (kg/kg)	Partial factor productivity of phosphorus (kg/kg)	Phosphorus recovery efficiency (%)
	Cane	Trash			
Phosphorus levels (A)					
A_1: 100% RD of P_2O_5	18.63	5.93	237.60	718.15	19.64
A_2: 75% RD of P_2O_5	12.92	4.67	233.72	867.38	18.76
SE m ±	0.43	0.12	17.16	18.23	0.42
CD at 5%	1.24	0.33	NS	52.03	NS
Time of application of phosphorus (B)					
B_1: 100% P_2O_5 at planting	14.26	4.89	183.02	736.50	17.47
B_2: 50% P_2O_5 at planting + 50% P_2O_5 at final earthing up	17.29	5.70	288.29	849.03	20.93
SE m ±	0.43	0.12	17.16	18.23	0.42
CD at 5%	1.24	0.33	48.98	52.03	1.20
Application of arbuscular mycorrhiza (C)					
C_1: No AM	14.42	4.94	163.59	716.49	17.67
C_2: AM	17.13	5.65	307.73	869.04	20.74
SE m ±	0.43	0.12	17.16	18.23	0.42
CD at 5%	1.24	0.33	48.98	52.03	1.20
Significant interactions	B x C	B x C	B x C	B x C	--
C.V.%	15.6	12.6	41.2	13.0	12.4
Control (No P_2O_5 application)	12.85	3.38	60.15	--	--

Table 4: Significant interaction effects between time of phosphorus application and arbuscular mycorrhiza in sugarcane

Treatments	Number of millable cane per hectare	DMY (kg/ha)		Cane yield (t/ha)	Green top yield (t/ha)	CCS Yield (t/ha)	P uptake (kg/ha)		Agronomic P use efficiency	Partial factor productivity of phosphorus
		Cane	Trash				Cane	Trash		
Significant interaction (B x C)										
B_1C_1: 100% P_2O_5 at planting without AM	71788	17096	6618	67.69	14.75	8.87	14.09	4.85	77.67	623.31
B_1C_2: 100% P_2O_5 at planting with AM	89399	17547	6709	91.44	21.40	11.93	14.43	4.93	288.38	849.68
B_2C_1: 50% P_2O_5 at planting + 50% P_2O_5 at final earthing up without AM	85970	18056	6984	87.36	20.18	11.45	14.76	5.04	249.51	809.68
B_2C_2: 50% P_2O_5 at planting + 50% P_2O_5 at final earthing up with AM	90259	22964	8412	95.68	22.74	12.13	19.82	6.37	327.08	888.39
SE m ±	2197	758	12	2.61	0.63	0.36	0.61	0.17	24.27	25.78
CD at 5%	6271	2163	634	7.45	1.79	1.02	1.75	0.47	69.27	73.58

Results and Discussion

Yield attributes

The tabulated data presented in Table 1 indicated that the NMC/ha were increased significantly with 100 percent RD of P_2O_5 level by 9 percent over 75 percent RD of P_2O_5 level, further it increased 9 percent with split application over basal P application and also increases with 14 percent with the application of AM biofertilizer in sugarcane. The interaction effect between time of phosphorus application as split application of P_2O_5 with AM (Table-4) recorded significantly highest NMC/ha (90259 /ha) which was found to be at par with an application of P_2O_5 as a basal dose with AM (89399 /ha) and split application of P_2O_5 with no use of AM (85970/ha), respectively. At harvest the average cane weight was found significantly highest with 100 percent RD of P_2O_5 level (1.102 kg), with splitting of phosphorus in sugarcane recorded 1.077 kg and with the application of AM recorded 1.099 kg, respectively. Phosphorus management observed significant results on Cane and trash DMY. At harvest among the phosphorus levels an application of 100 percent RD of P_2O_5 kg/ha was responded significantly highest cane and trash DMY (21870 and 7914 kg/ha), with splitting of phosphorus over basal application of P also recorded significant results for cane and trash DMY (20510 and 7698 kg/ha), and with the application of AM found (20256 and 7561 kg/ha) cane and trash DMY, respectively.

The data tabulated in Table 4 of significant interaction revealed that the cane and trash DMY at harvest were recorded significantly superior results with splitting of phosphorus and AM (22964 and 8412 /ha), respectively. The P application increases the dry matter production as it played a major role in the absorption and translocation of nutrients from the soil to the canopy. This also might be due to the better growth of plants and better uptake of nutrients. The increase in dry matter production might be due to the improved foraging ability, higher nutrient availability and uptake of nutrients with better assimilation. These results are in agreement of the findings with Chen *et al*. (2003) [5] concluded that with increase in P level the biomass of shoot and P content, higher total root length and more fine roots which were beneficial to P uptake by the plants. Such improvement in dry matter yield was also reported by Singh (2000) [13] and concluded that with increase in rate of P application increases the shoot dry weight.

The analyzed pooled data revealed that the millable cane and green top yield revealed that the yields were increased significantly with (10.39 and 22.45%) with the P level of 100 percent P_2O_5 kg/ha application while with the split application of phosphorus resulted in significantly increased with (15 and 18.77%) and an application of AM increased with (20.68 and 26.35%), respectively. These results are corroborating with earlier findings of Kadam *et al.* (1993) [6].

Higher yield are associated with higher levels and splitting of Phosphorus are obviously due to better root growth and increased uptake of nutrients favoring better growth for the crop. The significant interaction data presented in Table-4 shows that the splitting of phosphorus with AM recorded significantly highest cane and green top yield (95.68 and 22.74 t/ha) which was being at par with basal application of P_2O_5 with AM (91.44 and 21.40 t/ha). This could be due to availability of P and other nutrients at optimum levels.

Quality parameters

The experimental data presented in Table 2 showed that the sugarcane juice quality parameters *viz.*, the Sucrose (%), CCS (%) and Pol (%) in sugarcane juice were not responded significantly with phosphorus management. Purity percent of sugarcane juice at harvest was significantly influenced by application of AM (93.24, 93.22 and 93.23%) in pooled data analysis. Sugarcane juice P content (536.1 mg/l) was significantly responded by an application of 100 percent RD of P_2O_5 kg/ha while an application of AM responded significant results for phosphorus content in sugarcane juice at harvest (532.4 mg/l).

The CCS yield (t/ha) was found significant results with an application of 100 percent RD of P_2O_5 kg/ha (11.88 t/ha) over 75 percent RD of P_2O_5 kg/ha. While Phosphorus application in two splits responded significantly for CCS yield (t/ha) (12.13 t/ha) over basal dose and also the use of AM recorded significant CCS yield (t/ha) (12.37 t/ha). The split application of phosphorus and AM recorded significant interaction effect in terms of CCS yield (12.13 t/ha) and which was found to be at par with basal application of phosphorus with AM (11.93 t/ha) and split application of phosphorus without AM (11.45 t/ha), respectively.

Phosphorus acquisition and use efficiency

An application of phosphorus level as 100 percent RD of P_2O_5 kg/ha in sugarcane the cane (18.63 kg/ha) and trash (5.93 kg/ha) P uptake were found significantly highest. While amongst the time of phosphorus application the P uptake by cane and trash (17.29 and 5.70 kg/ha) were recorded significant results. However, with the application of AM, the P uptake found significantly highest results for cane and trash uptake (17.13 and 5.65 kg/ha). These results are in line with the findings of Matin *et al*. (2010) [7]. The application of phosphorus increased the drymatter production as it played a major role in the absorption and translocation of nutrients from the soil to the canopy. The positive effect of P can be attributed to the development of root system which in turn absorbs more water and nutrients from the soil. This also facilitates release of more root exudates which may contain organic acids and phosphatase enzymes that have solubilisation effect and inorganic and organic P compounds, thus helping in more P uptake by the crop. This effect is magnified in presence of mycorrhizae. The experimental results are in agreement with the findings of Omollo and Ochola (2006) [9] who reported the positive and significant effect of P_2O_5 application on uptake of nutrients.

While at harvest by an application of AM responded significant results for cane and trash P uptake (17.13 and 5.65 kg/ha). The phosphorus application as in split (50% P_2O_5 at planting + 50% P_2O_5 at final earthing up) with the use of AM observed significantly superior results for cane (19.82 kg/ha) and trash (6.37 kg/ha) P uptake (Table 4). AM-fungi are known to be effective in increasing nutrient uptake, particularly phosphorus and biomass accumulation of many crops in low phosphorus soil Turk *et al*. (2006) [15].

The AE was not recorded statistically difference by the levels of phosphorus. While, the time of P_2O_5 application as split application of phosphorus recorded significantly highest results for AE (288.29 kg cane/ kg phosphorus applied). However, an application of AM also found significant results for agronomic efficiency (307.73 kg cane/ kg phosphorus applied). The AE found significantly responded with split application of phosphorus and use of AM (327.08 kg cane/ kg phosphorus applied) which was recorded at par results with basal application of P_2O_5 with AM (288.38 kg cane/ kg phosphorus applied) and split application of P_2O_5 with no use of AM (249.51 kg cane/ kg phosphorus applied).

Data presented in Table 3 revealed that the PFP was found significantly highest (867.38 kg yield/ kg P uptake) with an application of 75 percent RD of P_2O_5 kg/ha P level while the time of phosphorus application as a split application of P_2O_5 recorded significant results for PFP (849.03 kg yield/ kg P uptake) and with an use of AM observed significant results for PFP (869.04 kg yield/ kg P uptake). The significant interaction data presented in Table 4 revealed that the splitting of application of P_2O_5 with AM recorded significantly highest PFP (888.39 kg yield/ kg P uptake) and which was found at par with the basal application of P_2O_5/ha with AM (849.68 kg yield/ kg P uptake) and split application of P_2O_5/ha without AM (809.68 kg yield/ kg P uptake), respectively.

The data presented in Table 3 revealed that, with the highest P level recorded 18.76 percent phosphorus recovery efficiency (PRE%) while amongst time of phosphorus application as split application of P_2O_5 influenced significantly highest PRE (20.93%) over basal application of P_2O_5 and with an application of AM observed significant highest PRE of 20.74%.

Conclusion

With an application of phosphorus as 100 percent RD of P_2O_5 level found significant results in terms of yield attributes, yield, P content in juice and uptake of P in sugarcane. Thus, split application of P_2O_5 (50:50%) with the AM biofertilizer were found effective to increase the yield attributes which resulted into highest cane, green top yield, CCS yield, P uptake as well as enhancing phosphorus use efficiency in sugarcane under south Gujarat condition.

Acknowledgement

I express my sincere thanks to the authorities of Central Laboratory, Dept., of Soil Science and Agril. Chemistry, N.M.C.A, Navsari Agricultural University, Navsari for providing all Lab facilities for carrying out the research and also Mahatma Phule Krishi Vidyapeeth, Rahuri for providing financial support in the form of study leave is greatly acknowledged.

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