Int.J.Curr.Microbiol.App.Sci (2019) *8*(11): 167-176

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 8 Number 11 (2019)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2019.811.021

Soil Test based Phosphorus Nutrition as Cost Reduction Technology in Sugarcane

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Keywords

Phosphorus levels, Nutrient uptake, Juice quality, Cane and sugar yield

Article Info

Accepted:
04 October 2019
Available Online:
10 November 2019

A B S T R A C T

A field experiment was conducted at Regional Agricultural Research Station, Anakapalle in plant – ratoon sequence with different levels of phosphorus and uniform recommended dose of nitrogen and potassium under high P clay loam soils of North Coastal Andhra Pradesh during 2014-2015 and 2015-2016. The aim of this present study is to reduce/optimize the phosphorus fertilizer doses under high P soils. Results revealed that, significantly highest cane yields of 76.90 and 67.90 tha^{-1} was recorded with 70 kg P_2O_5 ha^{-1} in plant and ratoon crops, respectively and it was on par with 50 kg P_2O_5 ha^{-1} (76.47 and 64.47 tha^{-1}, respectively). Significant sugar yield response was observed to increasing levels of P upto 50 kg P_2O_5 $ha^{-1}$and highest sugar yields of 11.0 tha^{-1} and 8.80 tha^{-1} were recorded with 50 kg P_2O_5 ha^{-1} in plant-ratoon sequence. Experimental results clearly indicating the role of P in juice quality enhancement as juice quality was increased with increasing levels of P from 0 to 50 kg P_2O_5 ha^{-1}, later there was no significant changes in juice quality with increasing P levels up to100 kg P_2O_5 ha^{-1}. Results clearly showing the synergistic effect of P on nutrient uptake and use efficiency of all the macro nutrients as evidenced with macro nutrient build up in soils with increasing P levels. The findings of this study would help in reduction of 50 % P fertilizer dose under high P soils for achieving desirable yield levels and will in turn reduce the expenditure on P fertilizers without compromising cane yield, sugar yield, juice quality and soil fertility status.

Introduction

Sugarcane in Andhra Pradesh is one of the important commercial crops grown in a wide variety of soils from sandy loams to deep black soils. Soil fertility levels also vary from place to place, particularly soil phosphorus status, it was low in clay soils and medium to high status in clay loams and high status in sandy loam soils. As a consequence of high cost of water soluble chemically processed phosphatic fertilizers and poor P use efficiency due to fixation as insoluble phosphates, imbalance in NPK ratios are anticipated which eventually leads to reduced productivity of sugarcane. Continuous application of inorganic phosphate fertilizers along with available organic manures have accumulated residual available phosphorus exceeding levels needed for maximum crop yields. Knowledge of residual benefits from previously applied P is crucial to maximize economic returns to current P inputs. Many soils of the Visakhapatnam district contain available phosphorus concentrations above crop requirement due to continuous application of P fertilizers. Given that P is the most expensive primary nutrient on a unit basis in most cane producing areas, Sugarcane is capable of rapidly depleting the soil of nutrients, particularly N and K, so phosphorus build up can be observed in fields with continuous P fertilization. Delineation of optimum P level for higher productivity and to avoid wastage of precious P fertilizer thus becomes inevitable. In an era of ever increasing economic constraints and community pressure to maintain the integrity of the environment, there is the need to fertilize efficiently (McCray *et al.,* 2010). Over-application of fertilizers will not only affect the profitability of cane operations but also the loss of applied nutrients (Dodd and Sharpley, 2015 and Abdul Matin *et al.,* 1997). The most important tool in phosphorus management for crops is a soil test. Soil testing reveals the soil phosphorus levels and determines the recommended application amount of phosphorus for the crop to be grown. Several researchers have demonstrated the beneficial effect of soil test based balanced nutrition for higher productivity and cost reduction (Bokhtiar *et al.,* 2015). Consistent and representative soil sampling is very important for correct interpretation of soil test results. Soil testing is the most precise available tool to prescribe adequate P fertilization rates (Doddand Sharpley, 2015). However, some reports suggest results can be erratic. There is a need to continue research on adjusting and validating soil P testing and P fertilization practices for improved productivity and reduced fertilizer costs. This study evaluated with different levels of P fertilization along with common dose of recommended nitrogen and potassium under high phosphorus soils on cane juice quality, cane yield, sugar yield, nutrient uptake, nutrient use efficiency and soil fertility in plant-ratoon sequence of sugarcane.

Materials and Methods

A field experiment was conducted at Regional Agricultural Research Station, Anakapalle, Andhra Pradesh in clay loams (*Inceptisols*) during 2014-2015 and 2015-2016 in plant - ratoon sequence. The Experimental soils are neutral in reaction (7.33), non saline in conductivity (0.538 dSm^{-1}), medium in per cent organic carbon (0.55 %), low in available nitrogen (252kg ha^{-1}) and high status of available phosphorus (60.50 kg ha^{-1}) and available potassium (389 kg ha^{-1}). Different graded levels of phosphotic fertilizers were tested along with common recommended dose of nitrogen and potassium fertilizers. The treatment details are as follows T1 :112-0-100 kg NPK ha^{-1}), T2 : 112-17.5-100 kg NPK ha^{-1}, T3 : 112-35-120 kg NPK ha^{-1}), T4 : 112-52.50-120 kg NPK ha^{-1}), T5 : 112-70-120 kg NPK ha^{-1}) and T6 : 112-100-120kg NPKha^{-1}). Experiment was laid out in a randomized block design with 4 replications. Sugarcane was planted (var. 2001A63) at 80 cm spacing in the first week of February, 2015 and subsequent ratoon crop was maintained in First week of January, 2016 and harvested in December, 2017. Recommended dose of nitrogen fertilizers were applied at 0 and 45 days and different levels of phosphorus and common dose of potassium was applied at the time of planting. Initial soil samples were collected before planting and post harvest soils were collected after harvest of plant and ratoon crops, subsequently. Whole plant samples for plant analysis were collected during grand growth stage of the crop. Chemical analysis of soil and plant samples was done as per the standard procedures described by Jackson (1967). The total nitrogen content (%) in the dried plant sample was determined by microkjeldahl distillation method (Piper, 1966). The diacid extract (9:4 nitric acid: perchloric acid) was used for analysis of total phosphorus, potassium and micronutrients in plant samples. Concentration of nutrient was multiplied by yield for calculation of nutrient uptake. Nutrient use efficiency in this paper is calculated by dividing the difference in uptake between treated and control by the rate of fertilizer applied. Juice analysis was carried out prior to harvesting, observations on Juice quality i.e. percent CCS, percent sucrose and percent purity was estimated as per the method suggested by Meade and Chen (1971). Cane yield was recorded during harvesting. Sugar yields were computed from the cane yield multiplied with %CCS. In order to compare the effect of various treatments on yield and fertility status, Analysis of Variance (ANOVA) was performed using standard procedures for split plot design (Chandel 2002).

Results and Discussion

Effect of different graded levels of Phosphorus on Cane yield and Sugar yield

Data on cane yield, sugar yield and juice quality was presented in table 1. Among different levels of phosphorus, cane yields ranged between 68.92 (0 kg P_2O_5 ha^{-1}) to 76.90 t ha^{-1} (70 kg P_2O_5 ha^{-1}). With increasing phosphorus levels cane yields were increased from 17.5 kg P_2O_5 ha^{-1} (73.16 tha^{-1}) to 50kg P_2O_5 ha^{-1} (76.90 tha^{-1}), later further improvement in cane yields were not observed with increasing P levels. In sugarcane plant crop, significantly highest cane yield of 76.90 tha^{-1} was recorded with 70 kg P_2O_5 ha^{-1} and it was on par with 50 kg P_2O_5 ha^{-1} (76.47 tha^{-1}). Around 3.7 tha^{-1} cane yield was increased from 25 to 75 % increase in P fertilizer rates in plant crop. Subsequent ratoon crop recorded highest cane yield of 67.90 t ha^{-1} with 70 kg P_2O_5 ha^{-1} and lowest yield of 54.92 tha^{-1} was recorded in 0 kg P_2O_5 ha^{-1}. Among different P levels, cane yields ranged between 59.16 (12.5 kg P_2O_5 ha^{-1} to 67.90 t ha^{-1} (70 kg P_2O_5 ha^{-1}), An additional cane yield of 0.38 and 3.03 tha^{-1} in plant-ratoon sequence was achieved with a fertilizer dose of 100 kg P_2O_5 ha^{-1} (existing recommended fertilizer P dose) over 50 kg P_2O_5 ha^{-1}. Significant sugar yield response was observed to increasing levels of P upto 50 kg P_2O_5 $ha^{-1}$and highest sugar yields of 11.0 t ha^{-1} and 8.80 tha^{-1} were recorded with 50 kg P_2O_5 ha^{-1} in plant-ratoon sequence. If "P" is omitted, reduction of 2.03 and 1.79 tha^{-1} sugar yields in plant and ratoon crops, respectively was recorded. Among different P levels (17.5 & 50 kg P_2O_5 ha^{-1}) around 0.63 tha^{-1} sugar yield gap was observed in plant crop, where as in ratoon crop it was 1.06 tha^{-1}. Mean sugar yields of 10.18 and 8.89 tha^{-1} was recorded in plant and ratoon crops, respectively. Phosphorus (P) is essential for the synthesis of adenosine triphosphate and numerous other phosphorylated compounds (Ghube *et al.*, 2017). This nutrient also enhances photosynthetic activity and increases root development, leading to increased nutrient uptake, greater tillering, and higher yield in sugarcane. P deficiency in sugarcane induces biochemical change such that leaf phosphatase acid activity is negatively correlated with accumulated P (McCray *et al.*, 2017). Application of P fertilizer promotes root growth, stimulates tillering, influences milleable cane growth, and thereby sugarcane yield per ha (Pannu *et al.*, 1985). Besides yield, adequate P nutrition is conducive for higher sugar accumulation in cane tissues. Kumar and Verma (1999) observed that application of 50 kg $P_2O_5ha^{-1}$ and above increased cane yield significantly over the control (37.2 to 56.4 t ha^{-1}). Excessive use of N, P or K can impact negatively on recoverable sugar and on the economics of cane production. About 10 to 20% of applied P is utilized, much less than that of other nutrients like N and K (Oseni 1978). Present experimental results clearly denoting the adjustment in phosphorus fertilizer doses by 50 % reduction with the current recommended dose of P fertilizers i.e 100 kg P_2O_5 ha^{-1} under high P soils.

Effect of different graded levels of Phosphorus on Cane Juice quality

Experimental results indicating the role of P in juice quality enhancement as juice quality was increased with increasing levels of P from 0 to 50 kg P_2O_5 ha^{-1}, later juice quality was slightly reduced with increasing P levels to 100 kg P2O5 ha^{-1}. Highest juice sucrose of 20.24 and 20.10 % was recorded with 50 kg P_2O_5 ha^{-1} followed by 12.5 kg P_2O_5 ha^{-1} (20.13 and 19.85 %) in plant and ratoon crops, respectively (Table 1). Lowest juice sucrose of 18.14 and 18.25 % was recorded under P omitted plots. Percent Commercial Cane Sugar (CCS) varied from 13.02 (0 kg P_2O_5 ha^{-1}) to 14.37 (0 kg P_2O_5 ha^{-1}) in plant and 12.77 to 13.50 in ratoon crops, respectively. Mean percent juice sucrose of 19.09 and 19.18 % in plant and 13.55 and 13.08 % in ratoon crop was recorded. Among different phosphorus levels significant differences were not observed in juice quality parameters i.e juice sucrose and percent cane sugar, however highest juice sucrose and % CCS was observed in phosphorus applied plots than phosphorus omitted plots. It is well established that a certain minimum P content in juice is essential for clarification because it is needed to react with lime to form a precipitate. Work at the different sugarcane research stations showed that poor sugar filterability was nearly always associated with high P contents in sugar (Lionnet1997). However, this could be caused by poor clarification often due to low levels or unreactive P in juices, the residual P then finding its way into the sugar, thus, low levels of P in juice can lead to high levels in sugar. Further results from different investigations showed that locality has a highly significant impact on the P content of juice and is strongly influenced by soil and past fertilizer practices. This might be associated with the P may enhanced the activity of sucrose synthetase, which was responsible for sugar synthesis in sugarcane (Ghube *et al.*, 2017). It is clearly indicating that phosphorus plays a major role in juice quality and clearly indicating that application of 50 % of the recommended dose of phosphorus i.e. 50 kg P_2O_5 ha^{-1} can meet the nutrient requirement without deteriorating juice quality under high P soils.

Effect of different graded levels of Phosphorus on Nutrient Uptake

The perusal of data presented in table 2 regarding nitrogen uptake by whole plant showed that increasing levels of P significantly improved N uptake from 0 to 70 kg P_2O_5 ha^{-1}. Highest uptake of total nitrogen in plant (181 $kgha^{-1}$) and ratoon crop (161 $kgha^{-1}$) was recorded with application of 100 kg $P_2O_5ha^{-1}$which was at par with 70 kg P_2O_5 ha^{-1}. Nitrogen uptake by whole plant ranged between 132 to 181 $kgha^{-1}$ in plant crop and 106 to 161 $kgha^{-1}$ in ratoon crop, respectively. Highest uptake was recorded with 100 kg P_2O_5 $ha^{-1}$and lowest uptake was recorded in P omitted plots. Phosphorus uptake by plant crop was ranged between 51.2 to 64.9 $kgha^{-1}$ and 43.73 to 54.22 $kgha^{-1}$ in ratoon crop, respectively. Though highest uptake was recorded with 100 kg P_2O_5 ha^{-1}, it was on par with 70 kg P_2O_5 $ha^{-1}$and 50 kg P_2O_5 ha^{-1}. Highest potassium uptake by whole plant was 238 and 195 $kgha^{-1}$ in plant and ratoon crops, respectively, it was recorded in 70 kg P_2O_5 ha^{-1} and it was on par with 50 kg P_2O_5 ha^{-1}. Applications of fertilizers at optimum rate are responsible for greater root development followed by higher nutrient uptake and leaf area development that cause a significant improvement in yield (Rakkiyappan *et al.*, 2007). Further, this might be due to increased CO^2 assimilation resulting from increased nutrient uptake as reported in different studies (Mahajan *et al.*, 2012 and Uddin *et al.*, 2013).

It may be due to the higher concentration of N, P and K in stalks and dry matter accumulation that led to higher N, P and K uptake at higher level of fertilizers application. Improvement in N, P and K uptake by crop was reported with increased P levels (Sandhu and Mahal, 2014 and Gangadevi *et al.*, 2012, Sanusan *et al.*, 2009 and Yuanqiu *et al.*, 2007) and NPK levels (Arif *et al.*, 2010 and Sandhyakanthi *et al.*, 2014). Morris *et al.*, (2002) reported that P was an essential plant nutrient that contributed to optimum sugarcane yield. Thangavelu and Chiranjivi Rao (2002) reported that P uptake by dry leaves, green tops, stem and total uptake in above ground parts was associated positively with uptake of N and K and yield of cane and sugar at harvest. Alexander *et al.*, (2003) reported that N, P and K application beyond 100 per cent of the recommended dose had produced only marginal increase in cane and sugar yield. Information on nutrient uptake and nutrient use efficiency of sugarcane clones are essential for efficient nutrient management (Schumann *et al.*, 1998).

Effect of different graded levels of Phosphorus on Nutrient Use Efficiency

In sugarcane plant-ratoon sequence, Nitrogen Use Efficiency was increased with increasing levels of phosphorus and highest N use efficiency of 43.75 and 40.33 % was recorded with 100 kg P_2O_5 ha^{-1} in plant and ratoon crops, respectively and it was on par with 70 kg P_2O_5 ha^{-1} (41.07 %) in plant and 50 kg P_2O_5 ha^{-1} (39.64 %) in ratoon crop, respectively.

Significantly lowest nitrogen use efficiency of 24.11 and 28.93 % was recorded with 17.5 kg P_2O_5 ha^{-} in plant and ratoon crops, respectively (Table 2). Results clearly showing the synergistic effect of P on nitrogen uptake and use efficiency. Similar results were report by Mahajan *et al.*, (2012).

Mean nitrogen use efficiency of 34.46 and 37.40 % was observed in plant and ratoon crops, respectively. Phosphorus Use Efficiency was highest with lower rates of P application and low at higher rates of P application in plant crop but in ratoon crop reverse trend was observed as it was high under high P levels when compared to low levels.

In plant crop, it clearly shows the increasing fertilizer efficiency under high soil P status with booster dose of reduced recommended application. Reverse trend in ratoon crop is due to high nutrient requirement by ratoon crop compared to plant crop, hence lower levels can't meet the nutrient requirement coupled with low nutrient use efficiency (Bationoand Anand Kumar 2002). P Use Efficiency varied from 12.86 to 22.86 % in plant and 6.11 to 16.16 % in ratoon crops, respectively. Highest use efficiency in plant crop was observed with 17.5 kg P_2O_5 ha^{-1}, where as in ratoon crop highest efficiency was observed with 75 kg P_2O_5 ha^{-1}. Larger uptake is possible because roots can absorb P from solutions with very small P concentrations and P is maintained in solution by desorption from the solid phase of the soil. Provided Efficiency of soil and fertilizer phosphorus use that there is sufficient P on adsorption sites, from which it can be desorbed readily, and that the rate of release is adequate, plants will obtain enough P to meet their changing demand during the growing season (Halvorson 1985), mean P Use Efficiency of 16.09 and 12.55 % was observed in plant and ratoon crops, respectively. Potassium Use Efficiency varied from 36 to 55 % in plant crop and 48 to 66 % in ratoon crop.

Table.1 Effect of graded levels of soil test based phosphorus management cane juice quality and yield of sugarcane

Treatments	% Juice sucrose		% CCS		Cane yield (t/ha)		Sugar yield (t/ha)	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
T1:(112-0-120 kg NPK ha^{-1})	18.14	18.25	13.02	12.77	68.92	54.92	8.97	7.01
T2:(112-17.5-120 kg NPK ha^{-1})	20.13	19.85	14.18	13.24	73.16	59.16	10.37	7.83
T3:(112-35-120 kg NPK ha^{-1})	18.94	19.05	13.42	12.87	75.42	62.42	10.35	8.03
T4:(112-50-120 kg NPK ha^{-1})	20.24	20.10	14.37	13.50	76.47	64.47	11.00	8.80
T5:(112-70-120 kg NPK ha^{-1})	18.30	19.15	13.10	13.10	76.90	67.90	10.17	8.81
T6:(112-100-120 kg NPK ha^{-1})	18.80	18.70	13.31	12.98	76.85	67.50	10.20	8.71
Mean	19.09	19.18	13.55	13.08	74.62	62.70	10.18	8.20
S.Em±	0.45	0.36	-	0.19	2.43	2.15	0.475	0.33
CD (0.05)	0.86	0.78	NS	0.40	5.53	4.25	1.090	0.75
CV (%)	7.60	8.48	-	8.20	8.55	8.90	6.57	8.10

Table.2 Effect of graded levels of soil test based phosphorus management on Nutrient uptake and nutrient use efficiency of macro nutrients by sugarcane whole plant

Treatments	Nutrient uptake (kg/ha)						Nutrient Use Efficiency (%)					
	Plant			Ratoon			Plant			Ratoon		
	N	P	K	N	P	K	N	P	K	N	P	K
T1: (112-0-120 kg NPK ha^{-1})	132	51.2	165	106	43.73	129	-	-	-	-	-	-
T2: (112-17.5-120 kg NPK ha^{-1})	159	55.2	211	142	47.10	177	24.11	22.86	36.00	28.93	6.11	48.00
T3: (112-35-120 kg NPK ha^{-1})	166	56.4	234	148	49.70	182	30.36	14.86	42.00	41.57	10.59	53.00
T4: (112-50-120 kg NPK ha^{-1})	169	59.7	232	151	51.33	195	33.04	16.19	45.00	39.64	12.73	64.00
T5: (112-70-120 kg NPK ha^{-1})	178	60.2	230	159	54.06	190	41.07	12.86	53.00	36.52	17.16	61.00
T6: (112-100-120 kg NPK ha^{-1})	181	64.9	238	161	54.22	193	43.75	13.70	55.00	40.33	16.16	66.00
Mean	168	57.9	225	149	50.02	185	34.46	16.09	46.20	37.40	v12.55	58.40
S.Em^{+}	5.80	2.11			1.22	4.88	1.45	0.47	1.57	1.31	0.56	2.15
CD (0.05)	12.5	4.62	NS	NS	3.15	12.2	2.95	0.98	3.9	2.75	1.08	4.5
CV (%)	8.22	9.20			9.65	11.00	7.40	8.10	7.50	8.10	7.25	7.90

Table.3 Soil physicochemical properties of post harvest soils under different phosphorus levels

Treatments	pH		EC (dS/m)		OC (%)		Available macronutrients (kg ha^{-1})					
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant			Ratoon		
							N	P_2O_5	K_2O	N	P_2O_5	K_2O
Initial	7.33		0.538		0.55		252	60.50	389			
T1	7.49	6.96	0.431	0.731	0.53	0.59	251	56.60	381	236	52.35	280
T2	7.48	6.92	0.416	0.734	0.59	0.57	254	61.32	381	241	64.74	314
T3	7.19	6.94	0.514	0.690	0.54	0.55	255	66.92	392	248	72.13	325
T4	7.32	7.06	0.339	0.445	0.57	0.54	268	69.28	403	257	74.59	302
T5	7.56	6.76	0.283	0.375	0.60	0.61	266	75.52	437	254	75.04	336
T6	7.48	6.56	0.546	0.323	0.54	0.56	283	76.20	395	263	79.07	347
Mean	7.42	6.87	0.422	0.550	0.56	0.57	263	67.64	398	250	70.79	317
S.Em±						0.125	5.91	2.98	9.54	5.05	1.96	9.45
CD (0.05)	NS	NS	NS	NS	NS	0.036	12.90	5.22	21.22	11.65	4.01	22.00
CV (%)	-	-	-	-	-	7.50	10.73	8.94	7.38	11.50	9.12	8.56

Highest use efficiency was recorded with 100 kg P_2O_5 ha^{-1} and lowest efficiency was recorded with 12.5 kg kg P_2O_5 ha^{-1}. Mean KUE of plant –ratoon sequence was 46.20 and 58.40 %, respectively. Though nitrogen and potassium levels are same in all the treatments, variation in uptake and use efficiency among different treatments is due to synergistic effect of P with other macro nutrients. Phosphorus (P) deficiency is a major constraint to crop production and response to nitrogen (N) is substantial only when P is not limiting (Traore 1974). As per the Jagman*et al.*, (2017) Phosphorus use efficiency estimated for the world using the difference method was 16%. Du Toit (1962) reported that where ratoons had received somewhat excessive amounts of phosphate, the effect of P in lowering sucrose per cent cane was most pronounced, particularly in later ratoons, which had received the topdressing.

Effect of different graded Levels of Phosphorus on Soil fertility status

Post harvest soils are neutral in reaction with normal conductivity, there is no significant difference between soil reaction and electrical conductivity in between different P levels in plant-ratoon sequence. Significantly highest organic content of 0.61 % was recorded in the plots which received 70 kg P_2O_5 ha^{-1} in ratoon crop from its initial value of 0.55 %. However significant differences were not observed in post harvest soils of plant crop (Table 3). The results in the present study revealed that available nitrogen, available phosphorus and available potassium were built up in soils with increasing P levels compared to P omitted plots. The findings were in line with the results obtained by Rene *et al.*, (2017). In post harvest soils of sugarcane plant crop, significantly highest available nitrogen content of 283 kg ha^{-1} was recorded with 100 kg P_2O_5 ha^{-1} and lowest content of 251 kg ha^{-1} was recorded in P omitted plots. In ratoon crop also same trend was followed as it was significantly highest (263 kgha^{-1}) with 100 kg P_2O_5 ha^{-1} and lowest (236 kg ha^{-1}) with P omitted plots, might be due to synergistic effect of N and P (Rene *et al.*, 2017). Available phosphorus content varied from 56.60 to 76.20 kgha^{-1} in plant crop and 52.35 to 79.79 kg ha^{-1} in ratoon crop, respectively. Available P content increased with increasing levels of phosphorus and significantly highest content was recorded with 100 kg P_2O_5 ha^{-1} and lowest content was recorded with P omitted plots. Available potassium status also followed the same trend as it was high with high P levels and low with P omitted plots. Synergistic interactions are well known for N x P and N x K interactions in several studies conducted all over India (Aulakh and Malhi 2005 and Roy *et al.*, 2006).

The findings of this study would help in efficient use of P fertilizer for achieving desirable yield levels and will in turn reduce the expenditure on P fertilizers that are mostly imported by India and majority of other developing countries. Due to high removal of nutrients by the sugarcane crop, nutrient supply capacity of the soil must be known for balanced fertilizer application for achieving sustainable yields by soil test results. Balanced fertilizer application based on soil test results provide greatest opportunity for improving the nutrient use efficiency and cane yield without deterioration of cane juice quality and soil fertility. The findings of this study would help in 50 % reduction of P fertilizer dose under high P soils for achieving desirable yield levels and will in turn reduce the expenditure on P fertilizers without compromising cane yield, sugar yield, juice quality and soil fertility status.

Acknowledgements

The authors would like to thank the Acharya N G Ranga Agricultural University for execution of research work at Regional Agricultural Research Station, Anakapalle by providing financial support.

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How to cite this article:

Rama Lakshmi, Ch.S., A. Sireesha, T. Sreelatha, P. Jamuna and Bharatha Lakshmi, M. 2019. Soil Test based Phosphorus Nutrition as Cost Reduction Technology in Sugarcane. *Int.J.Curr.Microbiol.App.Sci.* 8(11): 167-176. doi: https://doi.org/10.20546/ijcmas.2019.811.021