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Impact of fertilizer levels on sugarcane yield and available nutrients of clay loam Soil: A sustainable approach

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Abstract
An experiment was conducted during 2013–14 at the Regional Research Station, Karnal, Haryana, to study the impact of fertilizer levels on sugarcane yield and the available nutrients of clay loam soil of experiment site. The experiment was conducted in randomized block design, comprising 12 treatments, *viz.* control (no fertilizer), N, NP, NPK, NPKS, NPK+Zn, NPK+Fe, NPK+Mn, NPKS+Zn, NPKS+Zn+Fe, NPKS+Zn+Fe+Mn and soil test based fertilizer application. The treatments were executed on clay loam soil having low organic carbon and N status and medium P and K status. The results of the experiment showed that the available N status was significantly higher where NPK + Fe was applied whereas available P, K and yield were found relatively higher where NPK+S was applied. The yield was found highest in treatment where balanced doses of NPK with micronutrients were added.

Keywords: micronutrients, NPK, soil fertility, Sugarcane, yield

1. Introduction

Sugarcane is one of the important commercial crops of sugar in the world. The FAO estimated that sugarcane was cultivated on about 23.8 million hectares in 115 countries of the world and produce about 133 million tonnes of sugar which is three fourth of the total sugar production (169 million tonnes) of the world (FAO, 2010) [6]. In, India highest production of 355 million tonnes of cane was recorded during 2006-07 cropping season from an area of 5.15 million ha (Anonymous, 2007) [1]. Whereas, in Haryana, the area under sugarcane cultivation during 2011-12 ranged from 0.74 lakh ha to 1.89 lakh ha and the average production was 72.3ha^{-1}.

However, in recent years, the yield of sugarcane is declining in most of the potential growth areas of India mainly due to shortage of water, cultivation on poor soils and imbalanced use of chemical fertilizers besides new pest insurgence. Among all aforementioned reasons, imbalanced fertilization is most important since it has been observed that sugarcane growers emphasize on the application of N only and generally do not apply P, K, secondary and micronutrients. Excessive use of nitrogen or exclusive use of N without the use of balanced fertilizer application causing soils to become deficient in phosphorus, potash and micronutrients. Higher doses of N coupled with lower levels of P and K fertilization in many sugarcane growing areas has resulted in soil degradation due to over-exploitation of native soil nutrients which is one of the main reasons for declining yield and low sugar recovery of sugarcane. Insufficient N levels reduce profit and yield, while excessive N can pollute both surface and groundwater. The excessive N also makes the plants susceptible to lodging and disease, resulting in decreased yield and increased input cost (Cassman *et al.*, 1996) [3]. Also, if N application is not synchronized with crop demand, N losses from the soil-plant system will be more leading to low N fertilizer use efficiency.

The use of phosphorus helps in increasing the cane yield and available P reserves of the soil. Therefore, the application of P @ 50 kg P_2O_5/ha both in plant and ratoon crop was recommended (Kumar *et al*. 2005) [10]. Similarly, continuous cultivation of sugarcane without K fertilizer decreased the available K and reserve K (non-exchangeable K and total K) content in the soil and hence its application is also recommended. K @ 50 kg K_2O/ha was found beneficial for increased cane yield and juice quality (Kumar *et al*., 2000) [11].

Apart from primary nutrients sugarcane yield is also affected by S and micronutrients such as Fe, Zn and Mn. Ghaffar *et al*. (2011) [7] reported that in micronutrient deficient soils, application of micronutrients like Mn, Zn, and Fe in addition to NPK fertilizers was necessary to obtain maximum benefits from sugarcane crop. Research findings of long-term experiments conducted with sugarcane at various locations in India revealed that application of N alone depleted the native P, K, S and micronutrient reserve of soil, thus causing significant yield loss (Swarup and Wanjari, 2000) [23]. Consequently, farmers are experiencing declining responses to N and P due to the omission of other essential nutrients in their fertilizer schedules.

Considering the aforementioned scenario, this experiment was conducted to study the impact of fertilizer levels on sugarcane yield and the available pool of nutrients in clay loam soil of the experimental site. The experiment is a sustainable approach to generate scientific information for the betterment of sugarcane growers as well as for maintenance of soil fertility.

2. Materials and Methods

The experiment was conducted at Regional Research Station, Karnal (29º 43'42.19' N, 76º 58'49.88' E, 253 m above mean sea level) of the CCS Haryana Agricultural University. Sugarcane seeds (setts) of variety 'CoH 119' were sown in furrows in March 2013. The texture of the soil was clay loam and its initial composition consisted of low organic carbon, available N and Fe; medium available P, K, S, Mn and Zn. (Table 1). The design of the plot was a randomized block with three replications. Each replication was further divided into 12 equal plots of size 6 m × 6 m in which nutrients were added as:

T_1: Control (No fertilizer)
T_2: N_{150}
T_3: N_{150} P_{50}
T_4: N_{150} P_{50} K_{50}
T_5: N_{150} P_{50} K_{50} + S_{40}
T_6: N_{150} P_{50} K_{50} + Zn_{25}
T_7: N_{150} P_{50} K_{50} + Fe*
T_8: N_{150} P_{50} K_{50} + Mn*
T_9: N_{150} P_{50} K_{50} + S_{40} + Zn_{25}
T_{10}: N_{150} P_{50} K_{50} + S_{40} + Zn_{25} + Fe*
T_{11}: N_{150} P_{50} K_{50} + S_{40} + Zn_{25} + Fe* + Mn*
T_{12}: Soil test based fertilizer application.

Nitrogen was applied @ 150 kg N ha^{-1} through urea, phosphorus @ 50 kg P_2O_5 ha^{-1} through diammonium phosphate, potash @ 50 kg K_2O ha^{-1} through muriate of potash, sulphur @ 40 kg $CaSO_4$ ha^{-1} and zinc @ 25 kg $ZnSO_4$ ha^{-1}. All phosphorus, potash, zinc and one-third N were applied at planting and remaining N was applied in 2 equal splits: first, at the second irrigation and second, at the fourth irrigation. The Fe and Mn were sprayed as 3 foliar sprays each of 1% $FeSO_4$ and 0.5% $MnSO_4$. The soil samples were collected at the post-harvest stage and analyzed for available nutrients. The available nutrients *viz.*, nitrogen, phosphorus, potassium, sulphur and micronutrients were estimated in the laboratory as per the standard procedure specified by Subbiah and Asija (1956) [22], Olsen *et al*. (1954) [16], Hanway and Heidal (1952) [8], Chesnin and Yien (1950) [5] and Lindsay and Norvell (1978) [12]. The data obtained from the experiment was statistically analyzed through OPSTAT online statistical software (Sheoran *et al*., 1998) [21].

Table 1: Initial soil composition before experiment.

S. No.	Parameters	Values observed
1.	Soil texture	Clay Loam
2.	pH	8.6
3.	EC(dS/m)	0.44
4.	Organic carbon (%)	0.36
5.	Available N (kg/ha)	125.3
6.	Available P (kg/ha)	10.2
7.	Available K (kg/ha)	129.2
8.	Available S (kg/ha)	12.2
9.	Available Fe (mg kg^{-1})	3.7
10.	Available Mn (mg kg^{-1})	2.6
11.	Available Zn (mg kg^{-1})	0.9

3. Result and discussion

3.1 Soil reaction and OC

Soil pH and EC are the inherent properties of soil and their changes are seldom rapid due to the buffering capacity of soil and lots of other factors governing their existence. That's why the addition of different nutrients to the soil has not shown significant changes in the soil pH and EC. Similarly, different treatments added to soil have shown a very slight change in the OC but are not significant (Table 2).

Table 2: Influence of different levels of fertilizers on soil pH, EC and OC

Treatments	pH (1:2)	EC (1:2) (dSm^{-1})	OC (%)
T_1	8.5	0.44	0.35
T_2	8.4	0.45	0.35
T_3	8.6	0.45	0.36
T_4	8.5	0.46	0.35
T_5	8.5	0.46	0.36
T_6	8.5	0.47	0.36
T_7	8.4	0.47	0.36
T_8	8.4	0.46	0.36
T_9	8.5	0.48	0.36
T_{10}	8.6	0.47	0.36
T_{11}	8.5	0.47	0.37
T_{12}	8.5	0.48	0.37
CD (5%)	NS	NS	NS
SE (M)	0.04	0.01	0.01

3.2 Available N and P

Post harvest analysis of the soil have shown that the treatments which consist dose of nitrogen (T_2 to T_{12}) have shown its increased availability (≥135.4 kg ha^{-1}) in the soil and those having no dose of nitrogen *i.e.* T_1 (105.9 kg ha^{-1}) have showed decline in the nitrogen availability as compared to initial nitrogen availability. The available N status was found significantly higher where NPK + Fe was applied whereas available P was found higher where NPK+S was applied. Similarly, the treatments which consist dose of phosphorous (T_3 to T_{12}) have shown its availability in the soil (≥11.4 kg ha^{-1}) and those having no dose of phosphorous *i.e.* T_1 and T_2 have shown a decline in the phosphorous availability as compared to initial phosphorous availability (Table 3). The application of N and P significantly enhanced the cane yield (≥62.83 t ha^{-1}) as compared to control (45.61 t ha^{-1}) which is equivalent to 46 % more yield in the balanced fertilized plot (T_{11}) as compared to control.

The results are in conformity to those of Muchovej and Newman, (2004) [14] and Naga Madhuri *et al.*, (2011) [15] who found that addition of Nitrogen to sugarcane results in highest cane length. The tallest canes were recorded when nitrogen is applied @ 336 kg N ha^{-1} followed by 280 kg N ha^{-1}. Similarly, Omollo and Abayo, (2011) found that sources and levels of P significantly increased tiller number, amount of millable canes, plant height and cane yield.

Table 3: Influence of different levels of fertilizers on available N, P and cane yield

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	Cane yield (t ha^{-1})
T_1	105.9	7.1	45.61
T_2	136.6	7.2	62.83
T_3	138.5	11.5	69.97
T_4	138.2	11.7	75.16
T_5	137.6	11.9	78.93
T_6	139.8	11.7	76.26
T_7	137.7	11.8	76.57
T_8	138.2	11.8	75.47
T_9	138.4	11.7	79.20
T_{10}	136.2	11.8	82.97
T_{11}	135.4	11.6	84.48
T_{12}	137.8	11.4	75.10
Pre sowing (initial)	125.3	10.2	NA
CD (5%)	2.9	0.4	3.20
SE (M)	1.0	0.1	1.08

3.3 Available K and S

Post harvest analysis of the soil have shown that the treatments which consist dose of potassium (T_4 to T_{12}) have shown its availability in the soil (≥177.7 kg ha^{-1}) and those having no dose of potassium *i.e.* T_1, T_2 and T_3 have shown a decline in the potassium availability as compared to initial potassium availability (Table 4). Similarly, the treatments which consists dose of sulphur (T_5, T_9 to T_{11}) have showed its availability in the soil (≥15.9 kg ha^{-1}) and those having no dose of sulfur *i.e.* (T_1 to T_4, T_6 to T_8, T_{12}) have shown decline in the sulfur availability as compared to initial sulfur availability (Table 4). The available K, S and yield were found relatively higher where NPK+S was applied as compared to control whereas overall highest yield was observed where balanced doses of fertilizers were added (T_{11}). The application of K and S significantly enhanced their availability in the soil as well as increased the yield. The balanced application of K and S have increased their availability in the soil to the tune of 37 % and 38 % in T_{11} as compared to control. The better availability showed significant effects on yield and 46 % more yield was observed in the balanced fertilized plot (T_{11}) as compared to control.

The results are in confirmation of Johnson and Richard, (2005) [9] who reported that K has dominated role over S for increasing of sugarcane yield. In earlier studies, it was reported that the application of S fertilizer at the rate of 60 kg S ha^{-1} increased cane yield by 14.6 t ha^{-1} (Phonde and Jadhav, 2001) [18]. Satisha *et al*., (1996) [20] also reported that sulfur application gave significantly higher sugarcane yield and better soil availability, irrespective of source.

Table 4: Influence of different levels of fertilizers on available K, S and cane yield

Treatments	K (kg ha^{-1})	S (kg ha^{-1})	Cane yield (t ha^{-1})
T_1	112.5	10.4	45.61
T_2	114.9	10.5	62.83
T_3	117.3	11.0	69.97
T_4	177.7	11.1	75.16
T_5	180.7	15.9	78.93
T_6	177.9	12.2	76.26
T_7	178.0	11.3	76.57
T_8	179.0	11.3	75.47
T_9	179.5	16.6	79.20
T_{10}	178.3	16.2	82.97
T_{11}	178.8	16.5	84.48
T_{12}	177.7	11.8	75.10
Pre sowing (initial)	129.2	12.2	NA
CD (5%)	4.5	0.7	3.20
SE (M)	1.5	0.2	1.08

3.4 Available micronutrients (Fe, Zn and Mn)

Post harvest analysis of the soil has shown that the concentration of iron is non-significant in all the treatments since iron is applied to crop via foliar application and hence there are non-significant changes in the concentration of iron in the soil from the initial concentration. Similarly, the treatments having a dose of manganese showed non-significant changes in soil due to its foliar application (Table 5). Whereas, the treatments (T_6, T_9 to T_{11}) which consists dose of zinc applied as soil application have showed its availability in the soil (≥1.7 mg kg^{-1}) and those having no dose of zinc (T_1 to T_5, T_7, T_8, T_{12}) have shown decline in the zinc availability as compared to initial zinc availability (Table 5). The application of Zn in soil increased its availability in the soil to the tune of 52 %, 55 %, 55 % and 60 % in treatments T_6, T_9 to T_{11} as compared to control.

The results of the experiment are in support of those of Ghaffar *et al*., (2011) [7] who found that application of micronutrients like Zn, Mn and Fe in addition to NPK fertilizers was necessary to obtain maximum benefits from sugarcane crop. Also, incorporation of different type of fertilizers and micronutrients can improve soil fertility and can increase cane yield and sugar recovery (Sarwar *et al*., 2009; Chattha *et al*., 2010; Atique-ur-Rehman *et al*., 2013 and Mellis *et al*., 2011) [19, 4, 2, 13].

Table 5: Influence of different levels of fertilizers on available Fe, Mn, Zn and cane yield

Treatments	**Micronutrients (mg kg^{-1})**			**Cane yield** (t ha^{-1})
	Fe	Mn	Zn	
T_1	3.4	2.2	0.8	45.61
T_2	3.4	2.1	0.8	62.83
T_3	3.4	2.2	0.9	69.97
T_4	3.4	2.3	0.9	75.16
T_5	3.5	2.4	0.9	78.93
T_6	3.6	2.4	1.7	76.26
T_7	3.8	2.5	0.7	76.57
T_8	3.6	2.5	0.7	75.47
T_9	3.6	2.6	1.8	79.20
T_{10}	3.8	2.6	1.8	82.97
T_{11}	3.8	2.7	2.0	84.48
T_{12}	2.9	2.3	0.9	75.10
Pre sowing (initial)	3.9	2.8	0.9	NA
CD (5%)	NS	NS	0.11	3.20
SE (M)	0.02	0.01	0.04	1.08

4. Conclusion

Based on the experimental findings, it can be inferred that availability of nutrients in the soil, as well as sugarcane yield, can be enhanced by judicious and balanced application of nutrients. The findings showed that various levels of fertilizers had a significant effect on cane yield as well as nutrient availability in soil. Hence, it can be suggested to the sugarcane growers that the application of balanced doses of nutrients is necessary for obtaining better yield as compared to skipping the doses of K, S and micronutrients. Balanced fertilization not only plays a key role in obtaining higher yield as well as beneficial for ensuring availability of nutrients for next cultivation. Balanced fertilization reduces the harmful effect of intensive cultivation on soil by avoiding overexploitation of native soil nutrients while maintaining soil fertility in a sustainable manner.

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