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Integrated effect of organic and inorganic fertilizers on yield, quality parameter and nutrient availability of sugarcane in calcareous soil

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Abstract

A long term experiment under rice – sugarcane plant – sugarcane ratoon I – sugarcane ratoon II – Moong rotation was started during May, 1999 at Sugarcane Research Institute, Pusa, Bihar to evaluate the long term effect of different levels of nitrogen applied either alone or in combination with organic manures on yield and quality parameter of sugarcane as well as on soil health. The number of tillers, millable cane count, sugarcane and sugar yield were significantly increased at higher level of N when applied with organic manure where as the effect of biogas slurry (BGS) was found more pronounced. Similarly, juice quality was also significantly enhanced at higher N level in conjoint with BGS. The depthwise distribution of organic carbon and available nutrients like N, P, K, S and Zn content in post harvest soil after sugarcane plant as influenced by long-term intensive cropping system and continuous addition of organic and inorganic fertilizers indicated that organic carbon content regularly decreased with increasing soil depth and the rate of decrease was more in treatment receiving organic manures. Among the organic manures, sulphitated pressmud was found more effective followed by blue green algae and green manuring in accumulating organic carbon in surface soil. The available N, P, K, S and Zn content was higher in surface layer and it decreases progressively along with the depth upto 120 cm in all the treatments however, the rate of decrease was more in treatment receiving organic manures than inorganic fertilizer alone.

Keywords: quality parameter, calcareous soil, nutrient availability, biogas slurry, sugarcane yield, depthwise distribution

Introduction

Sugarcane (*Saccharum officinarum* L.) is an important crop of India which is cultivated in an area of about 5 million ha with an average productivity of 68.6 t/ha. The crop is of long duration and nutrient exhaustive which removes about 2.05, 0.24, 2.28 kg NPK/t of cane production (Singh *et al.* 2007). Fertilizer use in India is inadequate, imbalanced, skewed and is in favour of N, P and K. The frequent and excessive use of chemical fertilizer has created problem like deterioration of soil health and ecology. It has been observed in recent years that yield of sugarcane has reached a plateau due to decline in factor productivity. The loss in organic matter in soil is the root cause for decline in factor productivity. Soil organic matter is key factor in maintaining the soil fertility as it is reservoir of nutrients and provides metabolic energy for biological processes. Restoration of organic matter is thus, needed for maintaining soil health and improving productivity.

The poor yield of sugarcane in Bihar is mainly due to erratic and imbalanced use of chemical fertilizer. The available soil nitrogen is low and addition of organic matter is not practiced. Thus, improving soil organic matter and soil fertility are important factors for sustainability of sugarcane. Sugarcane produces large amount of foliage (40 % of total biomass) and a good crop of sugarcane produces about 10 to 15 t of trash depending upon variety and growth. It contains on an average 0.35-0.057-0.542 %, N-P-K in addition to other secondary and micronutrients (Chandra *et al*. 2008) [1].

In any agro-ecosystem, soil receives considerable amounting of carbon through left-over biomass of leaf fall, stubbles, roots and root exudates as well as through external sources like farm yard manure and compost and many studies have revealed direct linearised relationship between soil organic carbon storage and gross annual carbon input to soil. Several long-term experiments conducted in India under irrigated conditions in locations ranging from sub-humid to semi-arid tropical climates, showed build up of soil organic carbon (SOC) with varying degree in all treatments, which annually received external application of FYM (Swarup and Wanjari 2000) [13]. Nitrogen has been recognized as a universally deficient plant nutrient. The nitrogen content in soil is not uniformly distributed in profile. In most of the soils total N content is high in the surface (0-15 cm) layer, and below these it decreases considerably. Kaistha *et al*. (1990) [5] reported that average available N content in a horizon was higher (300-500 ppm) than the underlying horizon; the available N showed a regular decrease with soil depth in all the pedons. Phosphorus, like any other plant nutrient is present in soil in two major components i.e. organic and inorganic. Organic P, which is mainly confined to the surface layer, is mineralized into inorganic forms. But the plants mainly depend on inorganic P form for their P requirements. Potassium being one of the most dynamic nutrients, its availability in different forms and combinations depends upon the equilibrium and kinetics reaction between forms of soil K, soil moisture contents, temperature and the concentrations of bivalent atoms in solution and on the exchange phase (Sparks and Huang 1985) [10].

Materials and Methods

A long-term field experiment is in progress since kharif 1993 at New Area Farm of Sugarcane Research Institute, DRPCAU, Pusa, Bihar with Rice-Sugarcane plant-Sugarcane ratoon1-Sugarcane ratoon 2 -Moong rotation. The initial properties of surface soil were pH (1:2, soil:water) 8.2, electrical conductivity 0.20 dS m^{-1}, Free $CaCO_3$ 27.5%, Organic carbon 4.96 g kg^{-1}, Available N 227 kg ha^{-1}, Available P_2O_5 26.4 kg ha^{-1}, Available K_2O 95.0 kg ha^{-1} and DTPA extractable Zn 0.65 mg kg $^{-1}$. The climate of the experimental site is humid sub-tropical. The mean annual temperature is 24.5 ^{0}C with maximum 36.1 ^{0}C during April and minimum of 7.6 ^{0}C in January. The mean annual precipitation is 1200 mm which is received during May to October. The soil of the experimental field has sandy loam texture. The experiment consists of eight treatments, each replicated four times in a randomized block design having plot size of 25 m x 9 m. The soil samples were collected after harvest of sugarcane (22nd crop). The treatments were T_1- $N_{50}P_{100}K_{100}$, T_2- $N_{100}P_{100}K_{100}$, T_3- T_1 + 20 t/ha biogas slurry, T_4- T_2 + 20 t/ha biogas slurry, T_5- T_1 + green manure (Moong), T_6- T_2 + green manure (Moong), T_7- T_1 + 10 t/ha sugarcane trash + 10 t/ha sulphitated pressmud and T_8- T_2 + 10 t/ha sugarcane trash + 10 t/ha sulphitated pressmud. Treatment N_{100}, P_{100}, K_{100} means 150 kg N, 37.5 kg P and 50 kg K. Nitrogen, Phosphorus and Potash were supplied in the form of urea, single super phosphate and muriate of potash, respectively. Nitrogen as per treatment was applied in split doses, half at the time of planting, one forth at the time of first irrigation and rest one forth at the time of earthing up i.e. with the onset of monsoon. Full doses of P and K were applied at the time of planting. Trash were chopped, moist with water and incorporated in soil.

Composite surface soil samples (0-15cm) from each plot were collected after sugarcane (22nd crop) in rice-sugarcane plant-sugarcane ratoon-sugarcane ratoon-moong rotation. These were air dried and pulverized to pass through 2 mm sieve. Organic carbon in soil was determined by a wet oxidation procedure of Walkley and Black (1934) [16] and available nitrogen was estimated by the alkaline permanganate method outlined by Subbiah and Asija (1956) [12]. For available P, soil samples were extracted with 0.5M $NaHCO_3$ (pH = 8.5) (Olsen *et al*. 1954) [8] and available K by extraction with 1N ammonium acetate (NH_4OAc) solution at pH 7.0 (Jackson 1973) [4]. Available S was determined by extracting soil sample with 0.15 % $CaCl_2$ (Williams and Stainbergs 1959) [17] and S in the extract was estimated by turbidimetric method (Chesnin and Yien 1951) [2]. The available Zn in soil was extracted with DTPA as outlined by Lindsay and Norvell (1978) [6] and estimated by using atomic absorption spectrophotometer. Cane juice was extracted with power crusher and juice quality was estimated as per method given by Spencer and Meade (1955) [11]. Sugar yield was calculated as sugar yield (tones/ha) = [S – 0.4 (B-S) x 0.73] x cane yield (t/ha)/100; where S and B are sucrose and brix percent in cane juice. Whole cane sample was analyzed for N, P and K content and their uptake was calculated.

Results and discussion

The perusal of data revealed that application of nutrients through both organic and inorganic sources recorded significantly higher number of tillers and millable canes over T_1 receiving 50 % N along with 100 % P and K alone through inorganic fertilizer (Table 1). The T_4 receiving 100 % NPK along with 20 t ha^{-1} BGS recorded significantly highest number of tillers (138000 plant) and millable canes (134000 plant) over T_1. A variation of 47.0 to 70.2 t/ha in sugarcane yield was recorded due to integrated effect of organic and inorganic fertilizer combinations (Table 1). Higher NPK levels as well as organic manures significantly increased the cane yield and the highest value was recorded at T_4 treatment receiving 100 % NPK along with 20 t BGS ha^{-1}. Similar findings of integrated nutrient application were also reported by Thakur *et al.* (2012) [14] and Virdia and Patel (2010) [14]. Sugar yield varied from 5.6 to 9.1 t ha^{-1} due to influence of different treatment combinations. The highest sugar yield was 9.1 t ha^{-1} in T_4, receiving 100 % NPK along with 20 t ha^{-1} BGS. As the green manuring was incorporated in previous rice crop, its effect was least among organic manure. Sugar yield is a function of cane yield, sucrose per cent and brix per cent of cane juice. The cane juice quality viz. brix, sucrose and purity coefficient in cane juice did not differ significantly due to different treatments. Commercial cane sugar (CCS) which is a function of cane yield and sucrose content exhibited similar trend of cane yield (Singh *et al.*2007; Thakur *et al.* 2012) [9, 14].

Depth wise distribution of nutrients

Organic carbon

The organic carbon content in surface soil (0-15 cm) varied from 4.79 to 5.43 g kg^{-1}, while that in 15-30, 30-45, 45-60, 60-90 and 90-120 cm depths, it ranged from 3.51 to 3.75, 2.31 to 2.81, 1.92 to 2.35, 1.32 to 1.75 and 1.00 to 1.45 g kg^{-1}, respectively (Table 2) under different treatment combinations. Organic carbon content regularly decreased with increasing soil depth irrespective of treatment, however, the rate of decrease was more in treatments receiving organic manures indicating that organic carbon accumulated in the surface soil. The highest organic carbon was recorded in treatment receiving SPM as source of organic matter (Majhi and Rout 2016) [7].

Available nutrients

The available N content in surface (0-15 cm) varied from 208 to 228 kg ha^{-1}, while that in 15-30, 30-45, 45-60, 60-90 and 90-120 cm depths, available N ranged from 185 to 204, 162 to 192, 136 to 158, 100 to 120 and 68 to 90 kg ha^{-1}, respectively (Table 2). The data revealed that irrespective of N levels and organic source, the decrease in available N was regular and almost uniform with increase in soil depth. Since N is highly mobile, it tended to leach down to the soil depth. The treatment effect on available N was significant and higher available N was recorded in treatment receiving 100 % NPK along with organic manures as compared to 100 % NPK alone. The highest available N (228 kg ha^{-1}) was recorded in the surface layer (0-15 cm) under the treatment receiving 100 % NPK along with 20 t ha^{-1} BGS. The available P content in surface soil (0-15 cm) varied from 26.4 to 50.8 kg ha^{-1}, while that in 15-30, 30-45, 45-60, 60-90 and 90-120 cm soil depth ranged from 18.2 to 28.2, 14.2 to 19.2, 10.0 to 15.2, 8.2 to 13.0 and 7.0 to 11.2 kg ha^{-1}, respectively (Table 3). There was drastic depletion in available phosphorus content along with depth especially from 0-15 cm to 15-30 cm depth. The rate of downward movement comprising organic manure as compared to inorganic fertilizer alone treatment may be due to solubilization of native as well as applied phosphate by organic matter. The treatment effect was significant at all depths of soil in increasing available P_2O_5. The highest increase was recorded in case of NPK + BGS which was at par with NPK + SPM. The available K content in surface soil (0-15 cm) varied from 107 to 118 kg ha^{-1}, while that in 15-30, 30-45, 45-60, 60-90 and 90-120 cm soil depth ranged from 99 to 111, 94 to 104, 89 to 100, 79 to 89 and 74 to 83 kg ha^{-1}, respectively under different treatment combinations (Table 3). The available K content was higher in surface layer and it progressively decreased downward upto 120 cm in all treatments. Higher value of available potassium in surface layer may be due to higher organic matter content which retain available K on exchange sites (Chhotaray *et al.* 2010) [3]. There was decrease in available K down the depth but the rate of decrease was very slow. The available K remain unaffected by treatments at all depths i.e. the increase in available K due to inorganic fertilizers and organic manures was non-significant.

The available S content in surface soil (0-15 cm) varied from 9.7 to 20.5 mg kg^{-1}, while that in 15-30, 30-45, 45-60, 60-90 and 90-120 cm soil depth ranged from 12.4 to 23.5, 14.9 to 26.0, 18.0 to 30.2, 15.9 to 26.6 and 12.6 to 23.0 mg kg^{-1}, respectively (Table 4). With increasing levels of nitrogen there was increase in available sulphur alongwith depth upto 45-60 cm beyond which the values were continuously decreased. The variation in available sulphur due to different treatments was significant at all the depths. Among the organic manures, the effect of SPM application was significantly superior over other sources at 0-15 and 15-30 cm depths, however, the effect was at par with BGS at lower depths in building available S in soil. The available Zn content in surface soil (0-15 cm) varied from 0.70 to 1.24 mg kg^{-1}, while that in 15-30, 30-45, 45-60, 60-90 and 90-120 cm depths available Zn ranged from 0.66 to 1.05, 0.52 to 0.92, 0.38 to 0.61, 0.26 to 0.49 and 0.16 to 0.33 mg kg^{-1}, respectively (Table 4). The available Zn content was higher in surface layer and it progressively decreased along the depth upto 120 cm in all the treatments. Although, the Zn levels in soil below 45 cm depth could not reach to the critical level but the downward movement was more in case of treatments receiving organic manure than inorganic fertilizers alone. Organic matter addition as well as N level significantly increased the Zn content in soil. The effectiveness of SPM was found superior over other treatments however, the effect of BGS was at par.

Table 1: Long term integrated use of inorganic fertilizers and organics on growth attributes, yield and quality parameters of sugarcane

Treatments	No. of tiller (000 ha^{-1})	Millable cane count (000 ha^{-1})	Sugarcane yield (t ha^{-1})	Sugar yield (t ha^{-1})	Brix (%)	Pol (%)	Purity coefficient (%)	Commercial Cane Sugar (%)
T_1 $N_{50}P_{100}K_{100}$	125	119	47.0	5.6	19.2	16.8	87.6	11.9
T_2 $N_{100}P_{100}K_{100}$	134	129	57.0	6.8	19.5	16.8	88.3	12.0
T_3 $N_{50}P_{100}K_{100}$ + 20t BGS	131	128	56.2	7.5	19.7	17.6	89.6	12.6
T_4 $N_{100}P_{100}K_{100}$ + 20t BGS	138	134	70.2	9.1	20.4	18.1	90.2	13.0
T_5 $N_{50}P_{100}K_{100}$ + GM (Moong)	128	121	55.4	6.9	19.6	17.5	88.6	12.5
T_6 $N_{100}P_{100}K_{100}$ + GM (Moong)	135	130	62.5	7.8	19.7	17.4	88.8	12.3
T_7 $N_{50}P_{100}K_{100}$ + 10t ST + 10t SPM	126	123	59.3	7.4	19.6	17.4	88.9	12.4
T_8 $N_{100}P_{100}K_{100}$ + 10t ST + 10t SPM	135	132	65.9	8.5	19.9	17.8	89.2	12.7
SEm±	2.4	2.1	1.8	0.2	0.3	0.3	0.4	0.2
C.D.(P=0.05)	7.0	6.0	5.2	0.6	NS	0.8	1.2	0.7

Table 2: Effect of Long term influence of organic carbon (mg kg^{-1}) and available nitrogen (kg ha^{-1}) on depth wise distribution of available nutrients

Treatments	organic carbon (mg kg^{-1})						available nitrogen (kg ha^{-1})					
	Depth (cm)						Depth (cm)					
	0-15	15-30	30-45	45-60	60-90	90-120	0-15	15-30	30-45	45-60	60-90	90-120
T_1 $N_{50}P_{100}K_{100}$	4.79	3.51	2.31	1.92	1.32	1.00	208	185	162	136	100	68
T_2 $N_{100}P_{100}K_{100}$	4.84	3.60	2.36	1.99	1.40	1.12	215	194	179	143	109	78
T_3 $N_{50}P_{100}K_{100}$ + 20t BGS	5.17	3.68	2.40	2.10	1.56	1.20	223	199	185	148	114	84
T_4 $N_{100}P_{100}K_{100}$ + 20t BGS	5.43	3.75	2.49	2.21	1.48	1.29	228	204	192	158	120	90
T_5 $N_{50}P_{100}K_{100}$ + GM (Moong)	5.05	3.50	2.33	2.03	1.38	1.19	215	191	177	140	105	72
T_6 $N_{100}P_{100}K_{100}$ + GM (Moong)	5.27	3.55	2.35	2.12	1.45	1.23	219	196	180	145	107	75
T_7 $N_{50}P_{100}K_{100}$ + 10t ST + 10t SPM	5.34	3.75	2.55	2.29	1.50	1.39	220	199	182	150	110	80
T_8 $N_{100}P_{100}K_{100}$ + 10t ST + 10t SPM	5.38	3.75	2.81	2.35	1.75	1.45	224	203	188	155	116	86
SEm±	0.05	0.04	0.04	0.03	0.04	0.02	4	4	4	4	4	3
C.D.(P=0.05)	0.14	0.11	0.11	0.09	0.11	0.06	11	11	9	12	11	10

Table 3: Effect of Long term influence of available phosphorous (kg ha^{-1}) and available potassium (kg ha^{-1}) on depth wise distribution of available nutrients

Treatments	**available phosphorous (kg ha^{-1})**						**available potassium (kg ha^{-1})**					
	Depth (cm)						**Depth (cm)**					
	0-15	**15-30**	**30-45**	**45-60**	**60-90**	**90-120**	**0-15**	**15-30**	**30-45**	**45-60**	**60-90**	**90-120**
T_1 $N_{50}P_{100}K_{100}$	26.4	18.2	14.2	10.0	8.2	7.0	107	99	94	89	79	74
T_2 $N_{100}P_{100}K_{100}$	27.6	19.5	15.4	11.6	9.5	8.5	108	103	97	93	83	76
T_3 $N_{50}P_{100}K_{100}$ + 20t BGS	28.5	20.6	16.0	12.0	10.1	9.3	114	105	100	95	85	78
T_4 $N_{100}P_{100}K_{100}$ + 20t BGS	30.8	22.2	19.2	15.2	13.0	11.2	118	111	104	100	89	83
T_5 $N_{50}P_{100}K_{100}$ + GM (Moong)	28.0	20.0	15.8	12.8	10.0	9.0	110	103	98	93	83	76
T_6 $N_{100}P_{100}K_{100}$ + GM (Moong)	28.3	20.1	16.0	13.0	10.4	9.5	112	104	99	94	85	77
T_7 $N_{50}P_{100}K_{100}$ + 10t ST + 10t SPM	28.7	20.5	16.8	13.2	10.5	9.8	113	106	100	96	85	78
T_8 $N_{100}P_{100}K_{100}$ + 10t ST + 10t SPM	29.3	21.2	17.3	14.0	11.3	10.8	115	108	103	98	88	82
SEm±	0.7	0.4	0.5	0.8	0.6	0.5	3	3	2	2	2	3
C.D.(P=0.05)	2.1	1.3	1.5	2.3	1.7	1.5	NS	NS	NS	NS	NS	NS

Table 4: Effect of Long term influence of available sulphur (mg kg^{-1}) and available zinc (mg kg^{-1}) on depth wise distribution of available nutrients

Treatments	**available sulphur (mg kg^{-1})**						**available zinc (mg kg^{-1})**					
	Depth (cm)						**Depth (cm)**					
	0-15	**15-30**	**30-45**	**45-60**	**60-90**	**90-120**	**0-15**	**15-30**	**30-45**	**45-60**	**60-90**	**90-120**
T_1 $N_{50}P_{100}K_{100}$	9.7	12.4	14.9	18.0	15.9	12.6	0.70	0.66	0.52	0.38	0.26	0.16
T_2 $N_{100}P_{100}K_{100}$	12.0	14.9	17.5	21.1	18.9	16.1	0.78	0.72	0.60	0.42	0.31	0.21
T_3 $N_{50}P_{100}K_{100}$ + 20t BGS	13.9	16.9	19.4	22.3	20.0	18.2	0.85	0.80	0.69	0.48	0.34	0.24
T_4 $N_{100}P_{100}K_{100}$ + 20t BGS	17.5	20.1	23.6	27.1	24.9	21.3	1.05	0.99	0.86	0.58	0.43	0.30
T_5 $N_{50}P_{100}K_{100}$ + GM (Moong)	12.8	15.7	18.2	21.7	18.8	17.9	0.84	0.78	0.66	0.44	0.32	0.22
T_6 $N_{100}P_{100}K_{100}$ + GM (Moong)	16.2	19.6	22.1	25.7	22.4	19.6	0.92	0.88	0.76	0.50	0.38	0.26
T_7 $N_{50}P_{100}K_{100}$ + 10t ST + 10t SPM	15.2	18.4	20.9	24.0	21.1	18.9	0.90	0.84	0.76	0.52	0.39	0.29
T_8 $N_{100}P_{100}K_{100}$ + 10t ST + 10t SPM	20.5	23.5	26.0	30.2	26.6	23.0	1.12	1.05	0.90	0.61	0.49	0.33
SEm±	0.6	0.8	0.9	0.8	0.8	0.9	0.01	0.02	0.02	0.02	0.01	0.01
C.D.(P=0.05)	1.8	2.8	2.7	2.5	2.4	2.7	0.04	0.05	0.05	0.06	0.04	0.04

Conclusion

Integrated use of chemical fertilizer with organic manures augmented sugar yield, quality of sugarcane yield, and soil fertility. However, it may be concluded that integrated use of organic and inorganic fertilizer not only sustained soil and crop productivity but protects soil health and prevents emergence of multiple nutrients deficiencies in soil system. The depthwise distribution of organic carbon and available N, P, K, S and Zn content indicated regular decrease with increasing soil depth but the rate of decrease was more in treatment receiving organic manures. The correlation between soil parameters like organic carbon, available N, P, K, S and Zn in different depth and yield as well as nutrients uptake by sugarcane were positive and significant.

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