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Research Paper

Effect of integrated nutrient management on growth, yield, quality and soil health of spring planted sugarcane (*Saccharum officinarum*) in West Bengal

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ABSTRACT

An experiment was carried out during 3 consecutive cropping seasons of 2013–14, 2014–15, and 2015–16 at Bethuadahari, Nadia, West Bengal to evaluate the effect of organic manure and biofertilizers in combination with inorganic fertilizer as the source of nitrogen (N) on growth, yield attributes, cane yield, juice quality, leaf nutrient and chlorophyll content, and soil health after harvesting of sugarcane (*Saccharum* spp. Hybrid complex) (cv. CoB 94164). The experiment consist of 7 treatments, viz. T_1, control; T_2, 100% recommended dose of N through inorganic; T_3, 75% recommended dose of N through inorganic + 25% recommended dose of N through FYM; T_4, 50% recommended dose of N through inorganic + 50% recommended dose of N through FYM; T_5, T_3 + *Azotobacter*; T_6, T_3 + *Azospirillum*; T_7, T_3 + *Azotobacter* + *Azospirillum*, respectively in a randomized block design (RBD) with 3 replications. The results revealed that, application of N through organic manure and biofertilizer along with chemical fertilizer increased growth characters, viz. leaf-area index (LAI), total dry matter (TDM), chlorophyll content and N, P, K and S concentration in leaf tissues as compared to inorganic fertilizer alone. The maximum cane yield (86.10 t/ha) and sucrose content (17.52%) were recorded under the treatment T_7 (75% recommended dose of N through inorganic + 25% recommended dose of N through FYM + *Azotobacter* + *Azospirillum*). Cane yield exhibited significant positive correlation with different growth and yield attributes as well as with juice quality and vice-versa. The organic carbon, available N, P_2O_5 and K_2O contents of soil increased slightly after harvest of the crop due to the incorporation of organic manures and biofertilizers in soils initially. Thus, 25% of the recommended dose of nitrogen through inorganic sources could be replaced by FYM and biofertilizers for obtaining higher sugarcane yield along with improvement of soil health status.

***Key words* :** Biofertilizer, Farmyard manure, Inorganic fertilizer, Juice quality, Productivity, Soil health

Sugarcane, a hybrid of *Saccharum* spp., is one of the major commercial crops of industrial importance next only to cotton. In India, it is cultivated in an area of 4.93 million ha with a production of 348.45 million tonnes and an average productivity of 70.7 tonnes/ha, though there is a wide variation in productivity across the different regions (Anonymous, 2016).

The crop is mainly grown under rainfed upland condition. This necessitates the inclusion of organic sources of nutrients in cane cultivation. Most soils of north central part of India are low in organic matter (OM), generally containing less than 1.5%, while 2.5 to 3.0% organic matter is necessary for sustainable crop production (Bhander *et al.*, 1998). Since sugarcane is a long duration and exhaustive crop producing large biomass, it removes considerable amount of nutrients from the soil for its normal growth and development. A crop of 100 tonnes cane yield may remove 140 kg N, 34 kg P and 332 kg K from the soil (Dang *et al.*, 1995). Besides, there is considerable loss of nutrients through leaching, denitrification, volatilization etc. To replenish these nutrients, addition of organic manures and inorganic fertilizers at an appropriate time and in optimum balance is essential.

Farmyard manure is applied as organic manure for crop production. On an average, well decomposed farmyard manure contains 0.5% N, 0.2% P_2O_5 and 0.5% K_2O. Rabindra *et al.* (1990) reported that continuous application of farmyard manure along with NPK fertilizers improves physico-chemical properties of soil, cane yield and juice quality as a whole. Balanced use of organic, inorganic and biofertilizers is essential to maintain a good physical and

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chemical environment, also serve as an energy source for the soil microbial biomass and sustain sugar productivity. Integrated nutrient supply has proved superior to the use of its components separately (Singh and Yadav, 1992). For sustainability in sugarcane and sugar production, neither inorganic fertilizers nor organic manures alone but their integrated use has been observed to be highly beneficial (Banger *et al.*, 1994). The integrated use of organic manures and inorganic fertilizers not only sustain soil and crop productivity but also protects soil health and prevents emergence of multiple nutrient deficiencies in soil system (Umesh *et al*., 2013). Viridha and Patel (2010) reported the possibility of saving 25% N when organics were applied along with bio–fertilizers (*Azotobacter* + phosphate solubilizing bacteria). Hence, the present investigation was undertaken to evaluate the effects of farmyard manure and biofertilizers application alongside inorganic fertilizers on growth, yield and quality parameters of sugarcane as well as soil properties in Indo-Gangetic plains of West Bengal.

MATERIALS AND METHODS

A field experiment was conducted during 3 consecutive cropping seasons, viz. 2013–14, 2014–15 and 2015–16 at the research farm, Sugarcane Research Station, Government of West Bengal, Bethuadahari, (23°36' 54" N, 88°22' E and with 15 m above mean sea-level), Nadia, West Bengal, India. The experimental site was located in the agro-ecological zone-III. The experiment site has tropical type of climate. The experiment was carried out in the same field for the 3 consecutive cropping seasons without disturbing the field layout. Soil samples (0–15 cm depth) were collected from experimental plots, air-dried and passed through 2 mm sieve. The soil was loamy containing 52.84% sand, 34.0% silt and 13.16% clay with *p*H 7.6, 0.4% organic carbon (OC) and 192.4, 17.1 and 189.2 kg/ha available N, P_2O_5 and K_2O respectively. Cation exchange capacity (CEC) of the soil was 14.0 m eq/100 g soil.

The experiment was laid out in randomized block design with 3 replications. The 7 treatments were T_1, Control; T_2, 100% recommended dose of N (RDN) through inorganic; T_3, 75% RDN through inorganic + 25% RDN through farmyard manure (FYM); T_4, 50% RDN through inorganic + 50% RDN through FYM; T_5, T_3 + *Azotobacter;* T_6, T_3 + *Azospirillum;* T_7, T_3 + *Azotobacter* + *Azospirillum*. Urea, single super phosphate (SSP) and muriate of potash (MoP) were used as the source of N, P and K respectively. FYM was used as the source of organic manure. Full dose of SSP, MoP and FYM, and half dose of urea was applied in trenches and thoroughly mixed with soil prior to sett planting. The remaining half dose of urea was applied in 2 equal splits, half at tiller completion (90 days after planting (DAP)) and half at grand growth stage (180 DAP). FYM composition is given in Table 1. The biofertilizers were incubated with 200 kg of well decomposed FYM for 7 days and applied as basal.

Three-budded sugarcane setts were planted in the trenches in end- to -end system during February in all the 3 cropping seasons. Each plot had an area of 6.0 m × 5.4 m and 6 rows of cane were planted at an inter- row spacing of 90 cm. Sugarcane variety chosen for the experiment was 'Madhuri (CoB 94164)'.

Necessary intercultural operations like weeding, mulching, earthing-up, tying, control of pests and irrigation were done as and when required by the crop. Juice quality parameters like brix, pol and purity per cent were estimated in ten randomly selected canes from each replication. The data obtained were statistically analyzed following the method of analysis described by Gomez and Gomez (1984). Total dry-matter (TDM) produced was calculated at 3 different growth stages (120, 230 and 340 DAP respectively). Leaf samples (third and fifth) from top of main cane stalk were collected and separated into leaf blade and leaf sheath. Midribs were removed from the leaf blade and the samples were dried at 65°C and milled for nutrient analysis. Macro- and micro-elements like Ca, Mg, Cu, Zn, Mn and Fe, respectively were estimated using an atomic absorption spectrometry (Perkin Elmer 3111) as described by Petersen (2002). Leaf-area index and total dry-matter (TDM) production was calculated following the mentod described by Shimabuku *et al.* (1980). The chlorophyll content of cane leaf was determined at grand growth phase (230 DAP). Leaf chlorophyll was extracted with 80% acetone and was measured by spectrometry (Mahadevan and Sridhar, 1982). The number of millable canes were counted during harvesting period. Soil textural class was determined by hydrometer method and soil *p*H was measured in a 1:2.5 soil water suspension with a glass electrode *p*H meter. Available N was determined by macro Kjeldahl procedure and organic carbon by Walkley-Black method (Jackson, 1967). Available soil P was extracted with 0.5 M $NaHCO_3$ and the amount was determined by spectrophotometer. Exchangeable K was determined by flame photometry and available S by turbidimetric method (Black, 1965) in soil and plant leaf samples respectively.

RESULTS AND DISCUSSION

Growth attributes

Integrated use of inorganic and organic sources of plant nutrients along with biofertilizers resulted in considerable variation in different growth attributing characters of sugarcane (Table 2). Combined use of 75% RDN through inorganic + 25% RDN through FYM + *Azotobacter* +

Azospirillum (T_7) recorded the highest germination percentage (35.1) but there was no significant difference among the different treatments. Leaf-area index (LAI) increased very sharply up to 240 DAP and decreased slowly thereafter, until harvest in all the treatments. The maximum LAI (5.46) was obtained at 240 DAP with the application of 25% RDN through FYM + *Azotobacter* + *Azospirillum* inoculation along with 75% RDN through inorganic fertilizers (T_7) which was closely followed by treatments T_5 and T_6 (Fig. 1). This can be attributed to better availability of nutrients in soil because of addition of inorganic fertilizers in conjunction with organic manures and biofertilizers which resulted in more uptake. This increased absorption of nutrients in integrated treatments might have helped to improve the growth which led to higher leaf-area index. This result is in close conformity with the finding of Bokhtiar and Sakurai (2005) who reported that application of organic manure along with chemical fertilizer increased leaf-area index. Rosario *et al.* (1977) reported that with increase in LAI, there is a considerable increase in cane yield of sugarcane.

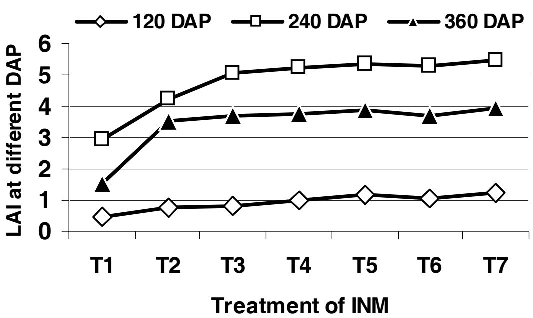

Fig. 1. Leaf-area index (LAI) under different nutrient management at different days after planting (DAP)

The dry-matter accumulation trend was similar to LAI trend. About 62–64% of the total dry-matter was produced between 120 and 240 DAP. The dry-matter accumulation was very slow during early growth stages (up to 120 DAP) under all fertilizer management treatments (Fig. 2). Thereafter, it increased very sharply up to 240 DAP following a gradual increment till harvest (360 DAP) which corresponds to the period of most rapid growth of sugarcane. At harvest stage, the highest dry-matter (511.7 t/ha) was recorded in T_7 plot and the lowest, (301.5 t/ha) in the control plot (T_1).

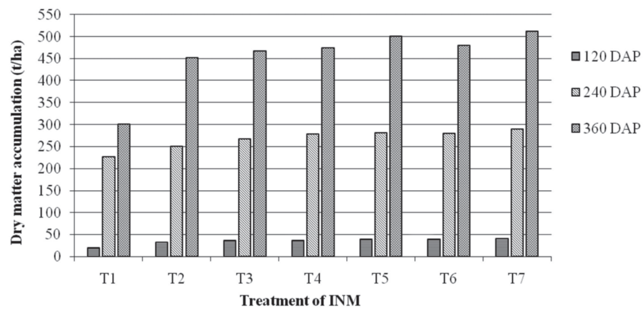

Fig. 2. Total dry-matter accumulation (DMA) under different nutrient management at different days after planting (DAP)

Yield attributes, yield and juice quality

Application of N through inorganic fertilizers along with FYM and biofertilizers significantly increased different yield attributes compared to the application of inorganic form of fertilizer N alone (Table 2). The highest number of millable canes (73,180/ha), maximum cane height (220 cm), single cane weight (0.85 kg) and cane diameter (2.39 cm) were recorded in T_7 treated plot where combined application of 75% RDN through inorganic + 25% RDN through FYM + *Azotobacter* + *Azospirillum* was given and that resulted in the highest cane yield (86.10 t/ha) (Table 2). The increase in cane yield may be attributed to the fact that inorganic fertilizers applied in combination with organic manures and biofertilizers are better utilized than inorganic source alone. This might be due to beneficial effect of FYM which improves the soil aeration, permeability, aggregation, water-holding capacity and biological properties, thereby enhancing the nutrient-use efficiency and ultimately leading to better plant growth (Paikaray *et al*., 2011). These results are also in line with the findings of Viridha and Patel (2010) who reported considerable increase in cane yield with the integrated use of FYM @ 25% RDN along with recommended dose of fertilizers and biofertilizers (*Azotobacter* + PSB). Gangwar *et al.* (2003) also reported that the substitution of 25% RDN through pressmud and FYM resulted in yield which was comparable to that obtained with 100% NPK applied through chemical fertilizers. Dinesh *et al*. (1996) also reported that application of 25% RDN through organic along with 75% RDN through inorganic fertilizers remained at par with application of 100% RDN through fertilizers in terms of cane and sugar yield.

The juice quality parameters of sugarcane like brix and

Table 1. Composition of farmyard manure (FYM) used in the experiment (on oven dry basis)

Organic manure	Moisture (%)	*p*H	OC (%)	Total N (%)	Avail P (%)	Exch. K (%)	S (%)	Ca (%)	Mg (%)	Cu (%)	Fe (μg/g)	Mn (μg/g)	Zn (μg/g)
FYM	40.0	7.0	15.6	1.21	0.09	0.39	0.18	4.5	0.48	38	6194	565	247

sucrose percentage were significantly influenced by different treatments. Highest brix (18.70%) and sucrose (17.52%) content were recorded with treatment T_7, which was on par with treatment T_5 and showed better performance as compared to inorganic fertilizer alone (Table 2). Enough storage and steady supply of nutrients due to mineralization of organic sources and release of readily available forms of nutrients from the inorganic fertilizers into the soil solution might have provided favourable condition for the absorption of required nutrients for physiological process which is a pre-requisite for adequate cane production with better juice quality. In the present study, treatments with soil inoculums of *Azospirillum*, *Azotobacter* and FYM application along with inorganic fertilizers substantially improved different growth attributes and yield attributes, which might have resulted in higher cane yield with superior juice quality. These results are in line with the findings of Gangwar *et al*. (2003), who showed that the application of chemical fertilizers alone reduced the value of quality parameters such as brix, sucrose and purity, while combination of both chemical fertilizers and organic manures improved them.

Leaf nutrient content

Application of inorganic fertilizers coupled with FYM and biofertilizers significantly influenced the nutrient content of leaf tissue at different growth stages of sugarcane. The N, P, K and S content were higher at tillering stage (TS) than grand growth stage (GGS) and finally decreased with advancement of the growth (Table 3). In contrast to treatment T_2, with sole application of inorganic fertilizer, the uptake of nutrients was higher with combined application of organic manure, biofertilizer and inorganic fertilizer (T_7 and T_5) at maturity stage of the sugarcane crop. These results were in close conformity with the findings of Kumar and Mishra (1992), who reported that a suitable

Table 2. Qualitative and quantitative characters of spring sugarcane cv. Madhuri (CoB 94164) under different nutrient management (pooled over 3 years)

Treatment	Germination (%)	NMC (,000/ha)	Cane diameter (cm)	Cane height (cm)	SCW (kg)	Brix (%)	Sucrose (%)	Cane yield (t/ha)
T_1, Control	29.25	34.84	1.65	185	0.61	16.20	15.23	57.11
T_2, 100% RDN through inorganic	30.15	49.34	2.23	209	0.75	17.82	16.69	65.79
T_3, 75% RDN through inorganic + 25% RDN through FYM	32.33	55.56	2.25	211	0.77	18.10	17.01	72.15
T_4, 50% RDN through inorganic + 50% RDN through FYM	33.27	62.58	2.31	213	0.79	18.22	17.38	79.22
T_5, T_3 + *Azotobacter*	34.37	68.26	2.37	218	0.82	18.49	17.45	83.25
T_6, T_3 + *Azospirillum*	33.44	64.22	2.32	215	0.80	18.32	17.33	80.27
T_7, T_3 + *Azotobacter* + *Azospirillum*	35.10	73.18	2.39	220	0.85	18.70	17.52	86.10
SEm±	–	3.26	–	1.74	0.02	0.13	0.12	1.79
CD (P=0.05)	NS	9.79	NS	5.22	0.07	0.38	0.35	5.38

NMC, no. of millable cane; SCW, single cane weight; RDN, recommended dose of nitrogen; FYM, farmyard manure; NS, non-significant; NMC, no. of cane millable; SCW, single case weight

Table 3. Major nutrients in leaf tissue at different stages of plant development as influenced by different nutrient management (pooled over 3 years)

Treatment	N (%)			P (%)			K (%)			S (%)		
	TS	GGS	MS	TS	GGS	MS	TS	GGS	MS	TS	GGS	MS
T_1, Control	1.45	1.23	1.01	9.11	8.98	8.01	1.43	1.35	1.21	15.13	13.77	13.15
T_2, 100% RDN through inorganic	1.81	1.65	1.47	10.07	9.75	9.23	1.55	1.43	1.35	16.53	14.48	14.20
T_3, 75% RDN through inorganic + 1.98 25% RDN through FYM	1.77	1.53	11.25	11.01	10.13	1.58	1.47	1.38	16.92	15.81	15.51	
T_4, 50% RDN through inorganic + 50% RDN through FYM	2.02	1.80	1.65	12.17	11.85	11.21	1.62	1.55	1.45	17.75	16.65	16.25
T_5, T_3 + *Azotobacter*	2.27	2.01	1.82	12.35	12.01	11.95	1.68	1.58	1.48	18.11	17.22	17.01
T_6, T_3 + *Azospirillum*	2.11	1.92	1.73	12.23	11.92	11.12	1.65	1.52	1.45	17.92	16.81	16.52
T_7, T_3 + *Azotobacter* + *Azospirillum*	2.31	2.11	1.92	12.59	12.32	12.01	1.73	1.63	1.52	18.91	17.87	17.35
SEm±	0.22	0.11	0.14	0.28	0.25	0.34	0.19	0.07	0.14	0.42	0.48	0.54
CD (P=0.05)	0.65	0.33	0.41	0.85	0.76	1.01	0.56	0.22	0.42	1.25	1.45	1.63

TS, tillering stage; GGS, grand growth stage; MS, maturity stage; RDN, recommended dose of nitrogen; FYM, farmyard manure combination of organic and inorganic fertilizer and split application of nitrogen may increase fertilizer efficacy and finally cane yield.

Chlorophyll content in leaf tissues

As Mg and N are the soil nutrients that constitute chlorophyll, effects of inorganic fertilizer in combination with FYM and biofertilizers on chlorophyll content in cane leaf was observed. An increasing trend of chlorophyll a, chlorophyll b and total chlorophyll was noticed in the FYM, in combination with inorganic fertilizer and biofertilizer (T_7) treated plot followed by treatment T_5 as compared to only inorganic fertilizer treated plot (T_2) (Fig. 3).

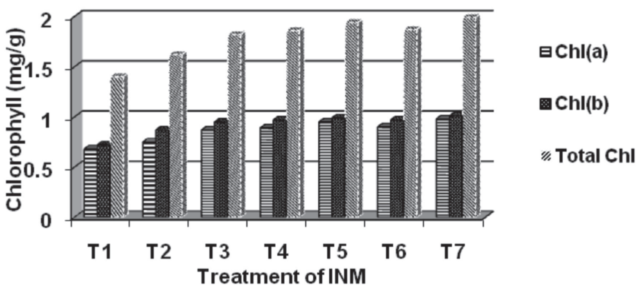

Fig. 3. Chlorophyll content (mg/g) in leaf tissue as influenced by different nutrient management treatments

Soil health status after harvesting of sugarcane

Substituting 25% of the recommended N through organics (FYM and biofertilizers) significantly improved the water infiltration rate. Maximum water infiltration rate (5.5 mm/hr) was found in treatments T_7, T_5, T_4 being statistically at par with treatment T_3 (Table 4). Although the application of N through organics (FYM and biofertilizers) along with inorganic fertilizers decreased bulk density and *p*H of soil over the control treatment but the differences were not-significant (Table 4). However, various treatments did not affect the electrical conductivity of soil (Table 4). These results are in close conformity linewith the findings of Singh *et al.* (2003) who reported that organic manuring improved physical properties e.g. bulk density and infiltration rate of soil in plant-ratoon system. The soils under investigation were low in organic C content and deficient in available N, P_2O_5 and K_2O content. After incorporation of FYM and biofertilizers in addition to inorganic fertilizer, improvement in organic C, available N, P_2O_5 and K_2O content over the control treatment was observed which helped to prevent the depletion of soil nutrient and maintain soil fertility. The maximum organic C, available N, P_2O_5 and K_2O content were recorded with the application of 25% RDN through FYM along with *Azotobacter* and *Azospirillum* inoculation and 75% RDN through inorganic fertilizer (Table 5). This result is in conformity with the findings of several workers (Rabindra *et al*., 1990 and Islam *et al.*, 1998) who reported that the use of organic manures in combination with inorganic fertilizer i.e. a judicious and balanced nutrition increased soil N, and available P, maintained and renewed organic matter and improved the physico-chemical properties of soil. Kumar (2012) also reported that there was a considerable increase in uptake of N, P and K as well as available soil N, P and K status when FYM was applied along with chemical fertilizers. Bokhtiar and Sakurai (2005) also reported the improvement of soil health status in terms of organic carbon, total N and available P, K and S content due to incorporation of organic manure through FYM along with inorganic fertilizers.

Correlation analysis

The correlation results indicated that cane yield was positively and significantly (at 1.0% level) correlated with the different growth and yield attributes as well as with cane quality (Table 6). Among the growth and yield attributes, yield had higher correlation with total dry-matter

Table 4. Physical properties of the soil after harvest of the plant crop as influenced by different nutrient management treatments (pooled over 3 years)

Treatment	Soil *p*H	EC (ds/m)	Bulk density (Mg/m^3)	Water infiltration rate (mm/hr)
T_1, Control	7.25	0.23	1.40	4.1
T_2, 100% RDN through inorganic	7.20	0.23	1.40	4.2
T_3, 75% RDN through inorganic + 25% RDN through FYM	7.19	0.23	1.37	5.4
T_4, 50% RDN through inorganic + 50% RDN through FYM	7.20	0.23	1.35	5.5
T_5, T_3 + *Azotobacter*	7.21	0.23	1.35	5.5
T_6, T_3 + *Azospirillum*	7.22	0.23	1.35	5.4
T_7, T_3 + *Azotobacter* + *Azospirillum*	7.20	0.23	1.35	5.5
Initial	7.25	0.23	1.40	4.1
SEm±	–	–	–	0.22
CD (P=0.05)	NS	NS	NS	0.65

Table 5. Soil fertility status after harvest of plant crop as influenced by different nutrient management treatments (pooled over 3 years)

Treatment	Soil organic C (%)	Available nutrients (kg/ha)		
		N	P_2O_5	K_2O
T_1, Control	0.41	195.7	16.2	195.3
T_2, 100% RDN through inorganic	0.47	236.1	19.5	221.3
T_3, 75% RDN through inorganic + 25% RDN through FYM	0.57	247.9	25.6	157.5
T_4, 50% RDN through inorganic + 50% RDN through FYM	0.65	256.5	28.9	264.7
T_5, T_3 + *Azotobacter*	0.62	253.1	26.3	262.5
T_6, T_3 + *Azospirillum*	0.61	251.9	25.9	261.5
T_7, T_3 + *Azotobacter* + *Azospirillum*	0.63	255.3	27.8	263.7
Initial	0.43	192.4	17.1	189.2
SEm±	–	3.58	1.77	5.38
CD (P=0.05)	NS	10.75	5.30	16.15

RDN, recommended dose of nitrogen; FYM, farmyard manure; NS, non-significant

Table 6. Pearson's product-moment correlation matrix of cane yield with growth attributes, yield attributes and juice quality

Parameters	Yield (cane)	Total dry-matter	Leaf-area at grand growth stage	Total chlorophyll	NMC	Cane diameter	Cane height	SCW	Brix	Sucrose
Yield (cane)	1	0.98895	0.94749	0.97993	0.99470	0.87654	0.91494	0.94639	0.92288	0.93482
Total dry-matter	0.98895	1	0.97942	0.99367	0.98996	0.91411	0.94201	0.96575	0.95376	0.96454
Leaf area at grand growth stage	0.94749	0.97942	1	0.98298	0.95611	0.95740	0.96684	0.96935	0.97716	0.98932
Total chlorophyll	0.97993	0.99367	0.98298	1	0.98444	0.91930	0.94800	0.96792	0.95960	0.96357
NMC	0.99470	0.98996	0.95611	0.98444	1	0.90988	0.94522	0.97214	0.95080	0.95197
Cane diameter	0.87654	0.91411	0.95740	0.91930	0.90988	1	0.99361	0.97718	0.99113	0.98480
Cane height	0.91494	0.94201	0.96684	0.94800	0.94522	0.99361	1	0.99370	0.99834	0.98690
SCW	0.94639	0.96575	0.96935	0.96792	0.97214	0.97718	0.99370	1	0.99493	0.98316
Brix	0.92288	0.95376	0.97716	0.95960	0.95080	0.99113	0.99834	0.99493	1	0.99083
Sucrose	0.93482	0.96454	0.98932	0.96357	0.95197	0.98480	0.98690	0.98316	0.99083	1

NMC, no. of millable cane; SCW, single cane weight

(r=0.98895**) and no. of millable cane (r=0.99470**) respectively. The growth attributes were also significantly correlated at 1.0% level with different yield attributes and cane quality parameters.

The results of this study suggest that FYM and biofertilizer incorporation are extremely important for maximizing and sustaining productivity of sugarcane and maintaining fertility status of the soils. Therefore, application of 75% recommended dose of N through inorganic + 25% recommended dose of N through farmyard manure (FYM) + *Azotobacter* + *Azospirillum* could be recommended for Indo-*Gangetic* alluvial soils of West Bengal for increasing productivity and to prevent nutrient depletion.

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