Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; SP5: 321-326

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(Special Issue- 5)
International Conference on
"Food Security through Agriculture & Allied Sciences"
(May 27-29, 2019)

Integrated effect of organic manure and *Azotobacter* with inorganic fertilizer on soil properties, yield and quality of sugarcane plant-ratoon system under calcareous soil

SK Sinha, Vipin Kumar and RK Prasad

Abstract
Field experiment were conducted for two consecutive seasons on spring sugarcane plant-ratoon system to investigate the integrated effect of organics *viz*. bio-compost (BC) and bio-methaneated distillery effluent (BMDE) with *Azotobacter* on growth, yield, quality and soil fertility of sugarcane. The mean data revealed that number of millable cane (NMC), cane yield, and sugar yield varied significantly due to integrated use of organic and inorganic fertilizer with *Azotobacter* in combination both in plant and ratoon crops. The significant increase in number of millable cane (NMC), cane yield and sugar yield Was recorded in the treatments receiving organic and inorganic fertilizer in combination with *Azotobacter* over control both in plant in ratoon crops. The mean data for NMC (70-98x10^3/ha), cane yield (61-80.4 t/ha) and sugar yield (7.13 - 9.75 t/ha) varied significantly. The highest number of NMC (98.90 X 10^3 ha^{-1}), cane yield (80.40 t ha^{-1}) and sugar yield (9.25 t ha^{-1}) was recorded in treatment receiving 50% N + 100% PK through inorganic fertilizer and 50% N through BC with *Azotobacter* (@ 5kg/ha). The residual effect of treatment receiving organic and inorganic fertilizer in combination with *Azotobacter* was also pronounced on NMC (96.3 x 10^3 ha^{-1}), yield (76.1 tha-1) and sugar yield (9.24 tha^{-1}), However, treatment receiving 50% N through BMDE was found on par with application of 50% N through BMDE. Both the organic sources improved performance of sugarcane. The uptake of nutrients (NPK) by plant and ratoon followed the similar trend as cane yield. The treatment receiving RDF along with *Azotobacter* improved productivity of sugarcane significantly over control (RDF). However, the efficiency of *Azotobacter* was more pronounced under inorganic treated plots. The reduction in pH and increase in EC, organic carbon and available nutrients (NP&K) of soil was recorded in treatment receiving organics either through bio-compost or BMDE. The available-N content of soil increased in *Azotobacter and organic* treated plots. The result clearly indicated that integrated use of BC / BMDE along with *Azotobacter* improved fertility status of soil with improvement in population of microbes.

Keywords: Bio-compost, *Azotobacter*, nutrient uptake, sugarcane

Introduction
Sugarcane (Sccharum spp. Hybrid complex), a C_4 plant is most efficient in converting physical and chemical energy (sucrose) on the earth fulfilling 80% percent of world's sugar demand. It is the second largest agro-processing industry of India next only to textiles and provides live hood to 50 million farmers. India is the largest sugar consuming country of the world and with 350 million tonnes of sugarcane production (2011-2012) stands next to Brazil. Among the various agronomic management practices in sugarcane crop: nutrient management alone contributes towards 30% of cane sugar production. A sugarcane crop yielding 100 t/ha removes 208 kg N, 53 kg P, 280 kg K, 30 kg S, 3.4kg Fe, 1.2kg Mn, 0.6 kg Zn and 0.2 kg Cu besides other micronutrients from soil (Shahi 2001) [24]. But, indiscriminate use of high level of chemical fertilizer, mostly N, P and K apart from their high cost often leads to nutritional in balance which ultimately causes deterioration in soil health and steadily decrease the crop yield. Sugarcane being a heavy feeder and long duration crop suffers from persistent nutrient unbalance due to gap between nutrient removal and application. Thus maintenance of soil fertility and crop productivity in a sustainable manner can only be possible through appropriate

combination of organics, inorganic and bio-fertilisers in an integrated manner to harness maximum advantage. In the first ratoon, application of nitrogen fertilizer is more effective for crop nutrition, constituting up to 70% of total nitrogen in the initial stage of development and decreasing through the cycle, reaching approximately 30% at harvest (Franco *et al*., 2011) [6]. Organic fertilizer has always been considered as a value input to the soil for crop production. No single source of plant nutrients i.e. chemical fertilizers, organic manures or bio-fertilizers can meet the entire nutrient demand of crop in intensive agriculture. Sugarcane (Saccharum officinarum hybrid complex) is an important commercial cash crop widely grown in tropical and sub tropical regions of India and crop are of long duration and nutrient exhaustive. That is a great need for nutrient replenishment through addition of organic material along with inorganic fertilizer for achieving higher yield and quality of sugarcane. Organic manures supply number of macro and micro-nutrients essential for healthy growth and development of sugarcane. For sustainability in sugarcane and sugar production, neither chemical fertilizer nor organic manures alone but their integrated use has been observed to be highly beneficial (Naik and Ballal 1968; Bangar *et al*., 1994; Chaudhary and Sinha, 2001) [15, 1, 5].

To address these problems improvement of the overall management of crop through integrated nutrient management protocols involving the synergistic and combinatorial application of inorganic fertilizers along with organic amendments and bio-fertilizers is very useful. Nitrogen fixing bio-fertilizers, *Azotobacter* in particular, have a greater potential on application in non-leguminous crops. The genus *Azotobacter* belongs to family *Azotobacter*iaceae including gram negative, free-living asymbiotic nitrogen fixing up to 10–20 kg N ha^{-1} (Kader *et al*. 2002) [11] that is readily isolated from the rhizospheric soils of a variety of non-leguminous crops *viz*., cereals like wheat, maize, rice, sorghum, cash crops like sugarcane, cotton and horticultural crops like tomato, brinjal, cabbage, potato etc. Apart from being a nitrogen fixer it also acts as a plant growth promoting (PGP) rhizobacteria by synthesis and secretion of PGP sub-stances like Vitamin B complex (nicotinic acid, pantothenic acid, biotin), phytohormones (heteroauxins or IAA, gibberel-lins, kinetin), siderophores and fungistatic compounds that are instrumental in enhancing growth and development of the plant which results in enhanced yield on inoculation. Thus, keeping in view the above facts, a field experiment was conducted to study the integrated effect of organic manure and *Azotobacter* with inorganic fertilizer on soil properties, yield and quality of sugarcane plant-ratoon system under calcareous soil.

Materials and methods

The field experiments were conducted on sandy loam highly calcareous soils for four years during years 2012-13to 2015-16 i.e., two years in plant crop and two years in ratoon-crop at Crop Research Farm, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. The farm is situated at $25^0$98'N latitude, $85^0$67'E longitude and at an altitude 52.0m above mean sea level and annual rain fall is about 1000mm.The climate of Pusa, Bihar is subtropical having soil ustochept, soil content free calcium carbonate more than 34% with soil is moderately fertile in nature. The initial experimental soil (0-30cm) had pH (1:2) 8.25, EC 0.32 dS/m, $CaCO_3$ 31.63%, Organic carbon 4.5g/ ha, N 228.0 kg/ha, P_2O_5 22.2kg/ ha, and K_2O 108.1 kg/ ha. The treatment details are T_1: N_{150} $P_{85}K_{60}$ (RDF), T_2: 100 % NPK + *Azotobacter*, T_3: 75 % N + 100%PK + *Azotobacter*, T_4: 50% N + 100%PK + *Azotobacter*, T_5: 25 % N + 100%PK + *Azotobacter*, T_6: 50 % N + 100%PK + 50% N through BC + *Azotobacter*, T_7: 50 % N + 100%PK + 50% N through BMDE + *Azotobacter*.

The BC was brought from New Swadeshi Sugar Mill, Narkatiagang, Bihar. The BC used in this experiment was characterized and it contains 1.53 % N, 1.50 % P and 3.10 % K. The recommended dose of fertilizer (RDF) 150–85–60 kg $N–P_2O_5–K_2O$ per ha were applied through Urea, DAP and MOP. The recommended dose of P and K was applied in all the treatments and the dose of N adjusted, BC and BMDE treated plot. The experiment was laid down in RBD with four replications. Plot size was 9.24 m x 5.40 m. Test crop was sugarcane (cv. B.O.147). BC was applied one month before sugarcane crop planting. Half of N and whole P and K were applied through inorganic fertilizer at the time of planting of sugarcane and the rest half N was top dressed at the time of earthing up. *Azotobacter* culture for the experiment was procured from Department of soil science TCA Dholi and RPCAU, Pusa. Five kilograms of charcoal based bio-fertilizer per hectare was applied in the furrow before plantation of the sugarcane clumps in the field. The bio-fertilizer was covered with soil by light earthing up followed by irrigation. The cane height, cane girth and cane yield data was recorded at the harvesting stage and the cane yield data was converted to tonne per hectare. The chlorophyll content was determined using Anderson and Boardman (1964) method. The quality data was recorded for brix % juice, pol% juice and purity% juice from composite juice of 10 canes in each of three replications as per standard procedures described by Chen James (1985) [4]. Brix was measured by hydrometer. The clarified juice was analysed with Sucromat (digital auto-matic saccharimeter) for pol% and purity%. Commercial Cane Sugar per cent (CCS%) was calculated by using Winter's formula. Sugar yield (CCS t/ha) was obtained by multiplying cane yield (t/ha) with CCS%. The crop was harvested and plant samples were analyzed for N, P, K and micro-nutrients by the standard procedure. The experimental soils (0-30 cm depth) were collected at the time of harvesting of ratoon crop (2^{nd} cycle) and analyzed for various physico-chemical properties using standard procedures. The uptke of nutrients by plant were calculated. Soil samples were analyzed for pH and EC in 1:2 soil suspension ratios. The organic carbon was estimated by method of Walkley and Black (1934) [29]. The available N was determined by using alkaline permanganate method (Subbiah and Asija 1956) [27], available P was analyzed by method described by Olsen *et al*. (1954) [16] and available K was determined by flame photo metrically as described by Jackson (1973) [9]. The soil physical properties were analyzed by method described by Black (1965) [3]. The available micronutrients cations were analyzed method describe by Lindsay and Norvel (1978) [13] the quality of juice was determined using procedure outlined by Spencer and Meade (1964) [26] and commercial cane sugar (CCS) was calculated. Soil microbial colonies were determined using the methods of plate culture count as described by Li *et al*. (2008). The *Azotobacter* establishment in the soil was assessed by analyzing the soil samples (0–15 cm) collected from each experimental plot by enumerating the viable cell count on Jensen's agar medium (cfu g-1 dry soil wt.) using dilution spread plating technique of the samples at initial, at tillering and at harvesting stages.

Results and Discussion

Effect on NMC, yield, Juice quality and sugar yield

Integrated nutrient application had significant impact on number of millable cane, yield and sugar yield of plant and ratoon of sugarcane (Table 1). The significant increase in cane yield was recorded in the treatments receiving organic manure in combination with fertilizer – N and *Azotobacter* over control (T_1). The treatment T_6 receiving 50 % N + 100% PK + 50% N through Bio-Compost along with *Azotobacter* produced highest NMC (98.90 x10^3/ha) and yield (80.40 t/ha) of plant crop. Similarly, residual effect of treatment T_6 was more pronounced on NMC (93.6 x 10^3/ha) and yield (76.1 t/ha) of ratoon crop. The result indicated that application of N through both from organic and inorganic sources along with *Azotobacter* were found beneficial for obtaining higher yield of plant and ratoon crop. However, difference in yield was non-significant among treatment T_2, T_3, T_4 & T_5 receiving only inorganic fertilizer along with *Azotobacter*. The immediate and quick supply of plant nutrient through inorganic source for plant growth and steady supply of plant nutrients by organics throughout the growth period resulted in higher yield due to integrated use of organic and inorganic-N. The organic manure released nutrients after decomposition and mineralization that would have increased the availability of plant nutrient on later stage and brought improvement in physical, chemical and biological properties of soil resulted in improved soil fertility and absorption of nutrient by plant. More NMC leads to more yield. The results are in agreements with findings of Sharma *et al*. (1999) [22], Nagaraju *et al*. (2000) [14]; Virdia and Patel (2010) [28]. This observation indicates possibility to save 50% N in plant cane and ratoon crop. Ratoons are highly exhaustive of nitrogen because of shallow root system, decaying of old roots, sprouting of stubble buds and immobilization of nitrogen. The integrated use of organic nutrient sources with inorganic fertilizer was shown to increase the potential of organic fertilizer (Heluf 2002) [8]. The sugar yield (CCS) followed the similar trend as cane yield. The highest sugar yield was recorded in treatment T_6 in cane plant (9.75 t/ ha) and response of sugar 36.75% and ratoon crops (9.24 t/ha) and response of sugar 47.13 %.

Hari and Srinivasan (2005) [7] have also observed better results regarding both the morpho-logical and yield parameters in sugarcane in combination treatment with bio-fertilizer and chemical fertilizer treatment than using either treatment alone. Similarly, Shankaraiah and Kalyanamurthy (2005) [21] have recorded positive influence of bio-fertilizer application on the yield parameters *viz*., height, weight and diameter of millable cane due to increasing levels of fertility and addition of PMC in general. Shaheen *et al*. (2007) [20] have reported enhanced plant growth, sugar yield and quality by application of two bacterial bio-fertilizers Azospirillium and/or *Azotobacter*.

Table 1: Effect of organic manure and *Azotobacter* with inorganic fertilizer on NMC, yield and sugar yield of sugarcane plant- ratoon system (pooled data of two years)

Treatments	NMC (000/ha)		Yield (t/ha)		Cane yield Response over control (%)		Sugar yield (t/ ha)		Sugar Yield Response over control (%)		Chlorophyll content (%)	Chlorophyll content increase over control (%)
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon		
T_1 : N_{150} $P_{85}K_{60}$ (RDF)	70.40	60.5	61.20	54.8	---	--	7.13	6.28	--	--	20.12	--
T_2 : 100 % NPK + *Azotobacter*	92.30	89.4	74.10	71.8	21.07	31.02	8.84	8.45	23.98	35.98	22.83	13.46
T_3 : 75 % N + 100%PK + *Azotobacter*	88.80	87.3	72.00	70.3	17.64	28.28	8.56	8.19	20.05	30.41	22.43	11.48
T_4 : 50% N + 100%PK + *Azotobacter*	78.60	75.6	66.80	63.5	12.41	15.87	7.85	7.62	10.09	21.33	22.24	10.53
T_5 : 25 % N + 100%PK + *Azotobacter*	71.40	68.8	61.90	56.7	01.14	03.46	6.92	6.66	02.94	06.05	21.82	08.44
T_6 : 50 % N + 100%PK + 50% N through BC + *Azotobacter*	98.90	93.6	80.40	76.1	31.37	38.86	9.75	9.24	36.75	47.13	25.63	27.38
T_7 : 50 % N + 100%PK + 50% N through BMDE + *Azotobacter*	91.30	90.3	79.20	75.8	29.41	38.32	9.74	8.98	36.60	42.99	25.42	26.34
SEm +	2.91	5.20	2.55	4.86	--	---	0.26	0.44	--	--	0.82	--
CD (P= 0.05)	8.98	16.03	7.88	15.00	--	--	0.82	1.33	--	--	2.55	--
CV	5.94	11.15	6.21	12.58	--	--	5.50	9.81	--	--	2.26	--

Chlorophyll content

The chlorophyll content is also positively influenced by inoculation may be partly because of the enhanced nutritional availability due to increased number of lateral rootlets and partly due to higher supply of fixed nitrogen to the growing tissue and organs supplied by diazotrophic inoculants. Hari and Srinivasan (2005) [7] advocated that inoculation of Azospirillum and *Azotobacter* with 100% urea application resulted in significant increase in total chlorophyll compared to the control treatment in sugarcane leaves sampled at different regular time intervals (*viz*., 20, 40 and 60th days). The highest (25.6 %) chlorophyll content was observed in BC treated plots which was at par with BMDE treated plot (25.4 %) over control (20.1 %).

Sugar Yield

The effect of organic amendment bio-fertilizer with organics (bio-compost, BMDE) along with inorganic fertilizer slightly improved sugar yield in plant cane and ratoon crop. The highest sugar yield (9.75 t/ha) in treatment T_6, which was at par with T_7 and lowest was observed in control. Hari and Srinivasan (2005) [7] in a field study to evaluate the response of sugarcane varieties to application of nitrogen fixing diazotrophs *viz*., *Azotobacter*, Azospirillum and Gluconacetobacter under different levels of fertilizer nitrogen, reported significant improvement in the yield and sugar content of bio-fertilizer inoculated sugarcane plants compared to un inoculated control.

Nutrient uptake

The nutrient uptake by plant and ratoon (Table 2) significantly increased due to application of organic manure and *Azotobacter* along with fertilizer- N through inorganic fertilizer over control. The highest uptake was recorded in treatment T_6 receiving 50 % N through BC + 50 % N through inorganic fertilizer + 100 PK along with *Azotobacter* and lowest in control. The combined use of BC/ BMDE along with *Azotobacter* and inorganic fertilizer resulted higher uptake of nutrient in T_6 and T_7 treatments. The data further revealed that among major nutrients relatively higher K uptake was recorded which was followed by N and P. The higher yield coupled with management of nutrients through organic and inorganic sources in T_6 resulting more nutrients uptake (Bhalerao *et al*. 2006) [2].

Table 2: Effect of organic manure and *Azotobacter* with inorganic fertilizer on uptake of nutrients in sugarcane plant-ratoon system (pooled data of two years)

Treatments	Uptake of macro nutrient (kg/ha)						Uptake of micro nutrient (g/ha)					
	Plant			Ratoon			Plant			Ratoon		
	N	P	K	N	P	K	Zn	Fe	Mn	Zn	Fe	Mn
T_1: N_{150} $P_{85}K_{60}$ (RDF)	138.20	12.89	147.4	123.7	11.54	132.0	42.22	556.9	195.8	37.81	498.68	175.36
T_2: 100 % NPK + *Azotobacter*	171.70	15.83	180.7	164.2	15.34	175.1	51.12	674.3	237.1	49.54	653.38	229.76
T_3: 75 % N + 100%PK + *Azotobacter*	164.70	15.60	175.5	162.9	15.23	173.5	49.68	655.2	230.4	48.50	639.73	224.96
T_4: 50% N + 100%PK + *Azotobacter*	154.80	14.67	164.9	145.3	14.14	156.7	46.09	607.8	213.7	43.81	577.85	203.20
T_5: 25 % N + 100%PK + *Azotobacter*	145.30	13.60	154.6	129.7	12.62	141.7	42.71	563.2	198.0	39.12	515.97	181.44
T_6: 50 % N + 100%PK + 50% N through BC + *Azotobacter*	191.20	18.39	198.4	176.4	17.17	190.1	55.47	731.6	257.2	52.50	692.51	243.52
T_7: 50 % N + 100%PK + 50% N through BMDE + *Azotobacter*	185.90	17.40	197.2	173.4	16.88	189.4	54.64	720.7	253.4	52.30	689.78	242.56
SEm +	3.55	0.62	6.47	7.81	1.42	8.36	2.71	4.49	2.89	1.70	11.30	11.82
CD (P= 0.05)	10.96	1.93	19.95	24.09	4.39	25.77	8.35	13.84	8.93	5.23	34.83	36.43
CV	3.74	7.00	6.44	8.81	16.78	8.75	9.61	1.20	2.21	6.37	3.21	9.55

Soil properties

Addition of organic manure with *Azotobacter* in combination with fertilizer -N significantly improved the soil fertility in terms of organic carbon in particular and availability of macro and micro nutrients (N, P, K, Zn, Cu, Mn and Fe) in general with reduction in bulk density of post harvest soil (Table 3). The application of organics in combination with inorganic fertilizer and *Azotobacter* significantly decreased pH lowest being in T_6 (8.08) receiving 50% N + 100% PK + 50% N through Bio-compost along with *Azotobacter* and highest in control (8.23). In contrast, significant increase in EC was recorded in bio-compost treated plot with maximum increase in T_7 (0.40dS/m). The reduction in pH might be due to production of weak organic acids due to decomposition of bio-compost and BMDE followed by increase in salt content of soil due to mineralization, which increase EC of soil. Bhalerao *et al.* (2006) [2] also reported that the soil pH reduced while EC increased due to application of bio-compost. There was significant effect of treatments receiving BC and BMDE on organic carbon and available N, P_2O_5, K_2O and micro nutrient content of soil after harvest of crop over control. The organic carbon increased by 44.18 percent in T_6 over control (T_1). The treatments varied significantly for available nutrients with N (228.7 to 273.7), P_2O_5 (25.52 to 38.15), K_2O (106.35 to 141.14) kg ha^{-1}. The buildup of soil available nutrient could be attributed to greater multiplication of microbes due to addition of organic manure, which helps in mineralization as well as solubilization of native nutrients. The data also indicated that cations especially Ca^{2+}+Mg^{2+} content of soils significantly increased in treatments of bio-compost. This might be resulted due to solubilization of nutrients by complexation of nutrients by humic and fulvic acid present in BC (Prasad and Sinha 1984) [17]. The results indicated that application of only inorganic fertilizer (T_1) was not effective for maintenance of soil fertility in sugarcane plant as reflected from initial value. Soil available nutrients and organic carbon sustained in all the organic manure and *Azotobacter* treated plots. The bulk density of post-harvest soil varied significantly (1.34 to 1.37 Mg/m^3) with addition of organic manure and *Azotobacter* (Table 4). The reduction in bulk density resulted in increased pore space of soil (46.41 to 49.81%) with increasing level of organic manure. The reduction in bulk density may be attributed to the build up of organic carbon content of soil in BC and BMDE treated plots. The maximum reduction (-0.09) units in bulk density was recorded in treatment T_6 as compared to control (T_1). The highest pore space (49.81%) and lowest bulk density (1.34 g/cm^3) was recorded in T_6 receiving 50 % N + 100% PK + 50% N through Bio-Compost along with *Azotobacter*, resulted in increased organic carbon content of soil. Beneficial effect of BC in improvement of physical and chemical condition of soil may be attributed to improvement in organic matter status in organic manure treated soil resulted in build up in soil fertility for sustainable sugarcane production. Sharma *et al*. (2006) [23], Sinha *et al*. (2014) [25]; Jha *et al*. (2015) [10] reported similar findings.

Table 3: Effect of organic manure and *Azotobacter* with inorganic fertilizer on soil properties (0-30 cm depth) after harvest of sugarcane plant-ratoon system

Treatment	pH	EC (dS/m)	Organic Carbon (g/kg)	Bulk density (g/cm^3)	$Ca^2 + Mg^+$ (m/L)	N (Kg/ha)	P_2O_5 (Kg/ha)	K_2O (Kg/ha)
T_1: N_{150} $P_{85}K_{60}$ (RDF)	8.23	0.32	0.43	1.37	10.71	228.7	25.52	106.35
T_2: 100 % NPK + *Azotobacter*	8.20	0.30	0.47	1.36	10.77	256.2	27.46	108.70
T_3: 75 % N + 100%PK + *Azotobacter*	8.16	0.30	0.48	1.36	10.79	238.4	27.96	111.50
T_4: 50% N + 100%PK + *Azotobacter*	8.18	0.31	0.50	1.35	10.93	236.9	26.60	110.00
T_5: 25 % N + 100%PK + *Azotobacter*	8.17	0.30	0.52	1.35	10.95	228.9	25.76	108.80
T_6: 50 % N + 100%PK + 50% N through BC + *Azotobacter*	8.08	0.37	0.62	1.34	11.23	273.7	38.15	141.14
T_7: 50 % N + 100%PK + 50% N through BMDE + *Azotobacter*	8.09	0.40	0.61	1.34	12.11	272.7	37.80	139.10
SE m+	0.01	0.01	0.04	0.008	0.09	4.36	0.38	6.43
CD (P= 0.05)	0.03	0.05	0.14	0.026	0.29	13.44	1.17	19.84
CV	0.18	8.93	15.32	1.094	1.50	3.05	2.21	9.45

Table 4: Effect of organic manure and *Azotobacter* with inorganic fertilizer on soil micro nutrients at harvest of sugarcane plant-ratoon system.

Treatment	Soil Micro Nutrients (mg/kg)			
	Fe	**Zn**	**Cu**	**Mn**
T_1: N_{150} $P_{85}K_{60}$ (RDF)	6.8	0.67	0.73	4.05
T_2: 100 % NPK + *Azotobacter*	6.9	0.69	0.75	4.10
T_3: 75 % N + 100%PK + *Azotobacter*	7.05	0.70	0.75	4.15
T_4: 50% N + 100%PK + *Azotobacter*	7.15	0.72	0.79	4.30
T_5: 25 % N + 100%PK + *Azotobacter*	7.20	0.68	0.77	4.45
T_6: 50 % N + 100% PK + 50% N through Bio-Compost + *Azotobacter*	8.20	0.80	0.88	4.85
T_7: 50 % N + 100% PK + 50% N through BMDE + *Azotobacter*	8.00	0.80	0.85	4.75
SE m±	0.10	0.00	0.00	0.11
CD (P=0.05)	0.33	0.02	0.02	0.35
CV	2.56	1.81	1.72	4.57

Microbial populations

The microbial population *viz*. bacteria, actinomycetes, fungi and *Azotobacter* significantly increased (Table-5) with addition of organic manure and *Azotobacter* over control. The highest population of bacteria (39.30 x 10^6), actinomycetes (17.50 x 10^4), fungi (21.4 x 10^5) and *Azotobacter* (46.70 x 10^4) cfug^{-1} were observed in treatment T_6 receiving 50 % N + 100% PK + 50% N through bio-compost along with *Azotobacter* and lowest in control. These results explained the improvement in microbial population of soil due to application of organics. Microorganism utilized organic carbon as a source of energy, nutrient and for nourishment which resulted in proliferation of soil microorganism. The increased activity of micro flora in organic manure and *Azotobacter* treated soil may be due to high organic matter build up with application of organic manure. The shift in microbial population signifies the maintenance of soil fertility and productivity due to faster rate of decomposition and smooth mineralization of organic materials. The results are in agreement with finding of Prasad (2005) [18] who observed positive and significant relationship of organic carbon with microorganism.

The quantity of bacteria, fungi, *Azotobacter* and actinomycetes increased by 74.10, 42.27, 36.93 and 33.81 % respectively over control. The *Azotobacter* inoculation resulted in multiplication and establishment of the culture in the inoculated field soil. Being PGP and plant probiotic bacteria *Azotobacter* count increase is a good signature of the improved soil microbial status and hence better soil health. (Satwant *et al*., 2012) [19]. Kaur *et al*. (2008) [12] have also reported establishment of larger populations of *Azotobacter* chrococcum in rhizospheric soil of wheat and clover plants in organic fertilizer treatments in comparison to chemical fertilizer alone treatments.

Table 5: Effect of organic manure and *Azotobacter* with inorganic fertilizer on microbial population of soils after harvest of sugarcane plant and ratoon. (Pooled data 2013-2014 & 2014-2015)

Treatments	Microbial population (Ratoon)							
	Sugarcane plant				Sugarcane ratoon.			
	Bacteria (10^6cfu g^{-1})	Actinomycetes (10^5cfu g^{-1})	Fungi (10^4cfug^{-1})	*Azotobacter* (10^4cfu g^{-1})	Bacteria (10^6cfu g^{-1})	Actinomycetes (10^5cfu g^{-1})	Fungi (10^4cfug^{-1})	*Azotobacter* (10^4cfu g^{-1})
T_1: N_{150} $P_{85}K_{60}$ (RDF)	22.40	12.30	14.92	34.90	22.40	12.30	14.92	34.90
T_2 :100 % NPK + *Azotobacter*	27.90	14.10	15.13	39.00	29.40	15.60	16.63	40.50
T_3 :75 % N + 100%PK + *Azotobacter*	28.70	14.40	15.82	40.90	30.20	15.90	17.32	42.40
T_4 :50% N + 100%PK + *Azotobacter*	31.50	15.00	16.43	43.10	33.00	16.50	17.93	44.60
T_5 :25 % N + 100%PK + *Azotobacter*	34.10	15.60	17.84	43.00	35.60	17.10	19.34	44.50
T_6 :50 % N + 100%PK + 50% N through Bio-Compost + *Azotobacter*	39.00	17.50	20.43	46.70	40.50	19.00	21.93	48.20
T_7 :50 % N + 100%PK + 50% N through BMDE + *Azotobacter*	38.10	15.70	19.32	45.90	39.60	17.20	20.82	47.40
SE m±	1.86	0.60	1.20	2.54	1.86	0.60	1.20	2.54
CD (P=0.05)	5.73	1.86	3.72	7.85	5.73	1.86	3.72	7.85
CV	10.31	7.00	12.13	1052	10.31	7.00	12.13	1052

Conclusion

Integrated use of BC/BMDE and inorganic fertilizer along with *Azotobacter* improved fertility status of soil, productivity with improvement in population of microbes.

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