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Study on the effect of organic and inorganic sources on the soil fertility, microbial population and nutrient uptake in sweet corn (*Zea mays* L. *saccharata*)

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Abstract
Sweet corn is emerging as a popular vegetable and not much research has been carried out so far in India in order to develop appropriate nutrient management practices with available renewable nutrient sources to lift up the productivity of the crop. Therefore, afield experiment was conducted insandy loam soils to test the various organic and inorganic nutrient input sources in sweet corn during *Rabi*, 2021-22 at Agricultural College Farm, Naira, Srikakulam. The experiment was laid out in randomized block design, replicated thrice with nine treatments *viz.*, T_1: Control, T_2: (100% RDF(180-60-60) NPK Kg ha^{-1}), T_3: (75% RDF + Biochar @ 2 ton ha^{-1} + Vermicompost @ 2 ton ha^{-1}), T_4: (75% RDF + Poultry manure @ 2 ton ha^{-1} + Waste decomposer), T_5: (75% RDF Paddy straw @ 10 ton ha^{-1} + Waste decomposer), T_6: (50% RDF + Biochar @ 2 ton ha^{-1} + Vermicompost @ 4 ton ha^{-1}), T_7: (50% RDF + Poultry manure @ 4 ton ha^{-1} + Waste decomposer), T_8: (50% RDF + Poultry manure @ 2 ton ha^{-1} + Paddy straw @ 10 ton ha^{-1} +Waste decomposer), T_9: (50% RDF + Biochar @ 1 ton ha^{-1} + Paddy straw @ 10 ton ha^{-1} + Poultry manure @ 2 ton ha^{-1} + Waste decomposer). Results revealed that, application of 100% RDF (180-60-60) NPK Kg/ha resulted in significantly higher primary nutrient uptake (NPK) by the stover of sweet corn plant. The application of organic along with inorganic nutrient input sources resulted in higher Nitrogen Use Efficiency *i.e.*, Agronomic Efficiency (63.57) and Apparent N Recovery (1.20). The integrated nutrient management treatments having substitution of 25 to 50% RDF with different organic sources of nutrition *i.e.*, biochar, poultry manure and paddy straw with waste decomposer resulted in higher microbial population. Whereas the highest returns per rupee invested was obtained with application of 100% RDF treatment.

Keywords: Biochar, inorganic, poultry manure, paddy straw, waste decomposer solution

Introduction

Maize (*Zea mays* L.) is globally known as "queen of cereals" due to its high genetic yield potential among the cereals and it is grown in an area of 193.7 million ha with a production of 1147.7 million MT and productivity of 5.75 tons/ha. Whereas in India it is cultivated in 9.9 million ha with 31.51million MT (2020-21) contributing nearly 9% to the national food basket. In Andhra Pradesh 3.01 lakh hectares of area occupied with the production of 21.21 lakh tones and productivity of 7055 kg/ha(Directorate of Economics and Statistics, Government of Andhra Pradesh, 2019-20).

Sweet corn (*Zea mays* L. sub sp. *saccharata*) is one of the varieties of maize which is being popularized in western countries and across the India due to its multiple uses, commercial value, good market support and fitting to crop intensification. Sweet corn is an excellent source of sugars, dietary fiber, vitamin-C, beta-carotene, niacin, in addition to calcium and potassium. Increase in productivity and profitability of sweet corn on sustainable basis is one of the important challenges before the researchers in India. Nutrient management is one of the most important factor affecting the growth and yield as it is considered as an exhaustive crop and requires both macro and micro nutrients for higher growth and yield. Health conscious individuals prefer to buy organically grown sweet corn, (Basha *et al.*, 2015) [3]. Therefore balance fertilization of maize through both organic manures and synthetic fertilizers is required for sustainable crop production (Subhankar Purohit *et al*., 2020) [20] Integrated nutrient management have multipurpose role on the improvement of soil fertility and crop productivity in a sustainable manner (Sindhi *et al*., 2018) [18]. Use of organic and inorganic sources not only helps in maintaining good physio-chemical characteristics and fertility of soils, but also increases the sweet corn yields markedly (Swain *et al*., 2019) [22]. Different types of organic manures like crop stubbles, animal urine, poultry manure, compost and biochar, when added to soil results in increase in microbial population ultimately improve in soil health as well as the sustainability of the soil (Sharif *et al*., 2003) [16]. Biochar has the capacity to increase soil water-holding capability, its hydrophobicity can significantly affect this ability (Devi and Saroha 2015) [5]. The poultry manure increased soil pH, organic matter (SOM), and N, P, K, Ca, and Mg contents of the soil, nutrients were released into the soil over the decomposition of poultry manure (Adekiya 2019) [1]. Combining the vermicompost and the specific rate of inorganic fertilizer that could effectively promote the growth and yield of sweet corn (Jeffrey 2020) [8]. With this background this study was conducted to determine the nutrient uptake and soil microbial health and evaluate the effect of combining the different organic and inorganic nutrient sources that could effectively promote the growth and yield of sweet corn.

Materials and Methods

A field experiment was conducted at Agriculture College Farm, Naira of Acharya N. G. Ranga Agricultural University which is geographically situated at $18^0 22'56''$ N latitude, $83^0 56'38''$ E longitudes and at an altitude of 12 m above mean sea level in the North Coastal Zone of Andhra Pradesh during *Rabi*, 2021-2022. The soil of the experimental site was sandy loam in texture, with pH 7.2, organic carbon 0.45%, available nitrogen 221 kg/ha, available P_2O_5 16.7 kg/haand available K_2O 245 kg/ha. The weather conditions during the crop growth period were normal.

The experiment was laid out in a randomized block design with nine treatments replicated thrice *viz*., T_1 Control, T_2 (100% RDF(180-60-60) NPK Kg/ha), T_3 (75% RDF + Biochar @ 2 t/ha + Vermicompost @ 2 t/ha), T_4 (75% RDF + Poultry manure @ 2 t/ha + Waste decomposer), T_5 (75% RDF + Paddy straw @ 10 t/ha + Waste decomposer), T_6 (50% RDF + Biochar @ 2 t/ha + Vermicompost @ 4 t/ha), T_7 (50% RDF + Poultry manure @ 4 t/ha+ Waste decomposer), T_8 (50% RDF + Poultry manure @ 2 t/ha + Paddy straw @ 10 t/ha +Waste decomposer), T_9 (50% RDF + Biochar @ 1 t/ha + Paddy straw @ 10 t/ha + Poultry manure @ 2 t/ha + Waste decomposer). The cultivar used for the experiment was Sugar-75. One seed per hill was dibbled at 20 cm apart with 60 cm row spacing on 19th January 2022. Poultry manure and paddy straw decomposed with waste decomposer solution was incorporated into the soil. Biochar was prepared under the low oxygen conditions by pyrolysis process with dried mesta sticks which has 33.6 percent recovery. Waste decomposer solution has been prepared by mixing 2 kg jaggery along with 200 litres water in a drum containing microbial culture and stored it for 5-7 days for complete decomposition. After a week, the solution was sprayed on a compost material such as paddy straw and allowed it to decompose. The compost was ready to use after 30 days. Pre-prepared biochar along with vermicompost were applied to individual plots as per treatments before sowing of crop. One third of the recommended dose of nitrogen, total dose of phosphorus and one third of recommended dose of potassium was applied at the time of sowing as basal dose as per treatments. Remaining nitrogen and potassium were applied as top dressing at knee high stage and tasseling stage uniformly. Nitrogen, phosphorus and potassium were applied in the form of Urea, Single Super Phosphate (SSP) and Murate of Potash (MOP), respectively.

The data recorded on primary nutrient (NPK) uptake (kg ha^{-1}) by stover at harvest, Nitrogen Use Efficiency, microbial population for fungi and bacteria and soil fertility status of N, P_2O_5 and K_2O sampled at harvest. Plants were selected based on random sampling method and the selected plant samples of sweet corn were ground in a Willey mill to pass through 40 mesh sieve. The ground material was collected in butter paper bags and later used for chemical analysis. Nitrogen, Phosphorus and Potassium content of stover were estimated by micro- Kjeldahl's method, vanado molybdate phosphoric yellow colour method (Jackson, 1973) [7] and Flame photometer (Jackson, 1973) [7]. NPK uptake (kg/ha) by stover at harvest of the individual nutrient was calculated by multiplying the nutrient content with stover yield (Piper, 1966) [13].

$$\text{Nutrient uptake by stover (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{Stover yield (kg/ha)}}{100}$$

Nitrogen use efficiency expressed in % utilization of nitrogen (Apparent recovery) and economic yield per unit of nitrogen applied (Agronomic efficiency) as indicated below (Reddy, 2018) [18].

$$\text{Apparent N recovery (ANR)} = \frac{\text{[N uptake in fertilized plot (kg/ha)] - [N uptake in control plot (kg/ha)]}}{\text{Fertilizer N applied (kg/ha)}}$$

$$\text{Agronomic efficiency (kg grain kg/ha N applied)} = \frac{\text{[Grain yield in fertilized plot (kg/ha)] - [Grain yield in control plot (kg/ha)}}{\text{Fertilizer N applied (kg/ha)}}$$

The soil microbial population was determined by serial dilution and spread plate technique. 1 g of the soil samples were added to 10 tubes contains 9 ml of distilled water, serially diluted. For bacteria enumeration 10^{-6} dilution and 10^{-4} for fungi were used. Pipette out 0.1 ml from these dilution series onto the surface of agar plate and spread evenly over the surface of agar using sterile glass spreader. The plates were warped with paraffin paper and incubated at 30 °C for 24 hour for bacterial and fungal isolation.

$$\text{CFU ml}^{-1} = \frac{\text{(Number of colonies)} \times \text{(Dilution taken)}}{\text{Volume of inoculum taken}}$$

The total cost of cultivation was calculated for the individual treatments on the basis of inputs used and prevailing market prices. Gross monetary returns were arrived at by multiplying economic yield with the prevailing market price of green sweet corn cobs and fodder. Net monetary returns were arrived at by deducting the cost of cultivation from gross monetary returns for each treatment. Benefit cost ratio was calculated by using the following formula.

$$\text{Gross returns} = \text{Fresh cob yield (kg/ha)} \times \text{Price (₹ kg}^{-1}\text{)}$$

$$\text{Net returns} = \text{Gross returns - Total operational cost (₹ ha}^{-1}\text{)}$$

$$\text{B: C Ratio} = \frac{\text{Net returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

Data were statistically analyzed by following the method of Fisher´s method of analysis of variance as suggested by Panse and Sukhatme (1985) [12]. Critical Difference (CD) was calculated wherever F-test was found significant. The level of significance used in F- test was 5%. Correlation between growth, yield and NPK uptakes with fresh cob yield were analyzed by XLSTAT software 2016.

Results and Discussion

Primary nutrient uptake (NPK) by stover in sweet corn

The primary nutrient (NPK) uptake of sweet corn stover sampled at harvest showed significant variation by the application of different combinations of organic and inorganic nutrient input sources (Table 1).

The highest NPK uptake by stover at harvest was recorded with the application of 100% recommended dose of fertilizers (T_2), but it did not show any significant variation with various integrated nutrient management treatments having substitution of 25 to 50% RDF with different organic sources of nutrition (T_3,T_4, T_5, T_6, T_7, T_8& T_9)which might be due to the greater capacity of applied organic manures to retain nutrients in forms that can easily be taken up by plants over a longer period of time. The nutrients in the inorganic fertilizer are already in the mineral form and it provides a ready source of nutrients to the crop and available within a short period of time. Whereas significantly lowest uptake of NPK was observed with the absolute control (T_1). Higher N, P and K uptake with recommended dose of inorganic fertilizer compared to other levels of nitrogen in organic form could be ascribed to the increase in the available nitrogen due to readily soluble nature, which might have increased the absorption. The Increase in NPK uptake with incremental levels of fertilizers was reported by Shetye *et al.* (2019) [17], Khan *et al.* (2018) [10], Ullasa *et al.* (2016) [23] and Spandana Bhatt (2012) [19].

Application of 100% inorganic input sources resulted in higher nutrient uptake as mineralization process was faster and thereby immediate release of nutrients elements with their quick soil availability facilitated in the higher plant uptake when compared with organic input sources like poultry manure, vermicompost and biochar. Slow release of nutrients from organic sources resulted in steady uptake by plant throughout its growth stages. The increased nutrient uptake might be accredited to favorable soil condition and also increased foraging capacity of roots which stimulates more vegetative growth in the crop plants. These results are in close consonance with Shakunthala *et al*. (2019) [15].

Nitrogen Use Efficiency

The perusal of the data presented in table1revealed that highest Apparent N recovery and highest Agronomic efficiency was registered with 50% RDF + soil incorporation of biochar @ 1 t/ha + paddy straw @ 10 t/ha along with poultry manure @ 2 t/ha decomposed with waste decomposer solution (T_9), whereas the lowest values were recorded with application of 100% recommended dose of fertilizers (T_2).

Microbial population

In sweet corn crop, the application of both organic and inorganic nutrient input sources in different combinations also influences the microbial population in the soil by taking fungi and bacteria into consideration.

The data (Table 2) regarding microbial population for fungi and bacteria sampled at tasseling and at harvest revealed the significant difference among the treatment combination of both organic and inorganic nutrient input sources.

The highest microbial population (Fungi and bacteria) was observed with application of 50% RDF along with poultry manure @ 4 t/ha decomposed with waste decomposer solution (T_7) at tasseling and at harvest. There was no significant difference in the microbial population noticed with treatments having substitution of 50% RDF *viz.*, 50% RDF along with poultry manure @ 2 t/ha + paddy straw @ 10 t/ha decomposed with waste decomposer solution (T_8) and 50% RDF + soil incorporation of biochar @ 1 t/ha + paddy straw @ 10 t/ha along with poultry manure @ 2 t/ha decomposed with waste decomposer solution (T_9) with that of T_7. While the lowest population of microbes was recorded under application of 100% RDF (T_2).

The application of organic sources of inputs leads to increase in microbial population. Various organic nutrient input sources such as poultry manure, vermicompost, biochar contains higher amounts of plant growth promoting substances, different types of enzymes etc. which in turn lead to enhance the population of microbes in the soil (Panchal *et al*., 2018) [11].

The decomposition of poultry manure increases the soil available nutrients with rapid action of increasing microbial population. The use of poultry manure in higher doses increases the level of available organic carbon content for soil microorganisms by elevating the rate of soil respiration and in turn, the organic carbon content impacts the activity and total population of microbes, resulting in greater CO_2 production. Respiration of soil at later stages, *i.e.,* tasseling gets diminished because there might be deficient in energy sources for microbes in the soil and hence the microbial activity gets declined. The application of poultry manure had significant effect on nitrifying bacteria activity (Increase by 50%) as reported by Hersztek *et al*. (2018) [6]. Increasing microbial population with incremental levels of poultry manure was also reported by Darwin *et al.* (2020) [4], Hersztek *et al*. (2018) [6] and Panchal *et al*. (2018) [11].

Soil fertility status after harvest of the sweet corn

Soil OC (%)

Post-harvest soil organic carbon did not show any significant variation among the treatments by the application of both organic and inorganic nutrient input sources. It was reduced after the harvest of the sweet corn crop as increase in fertilizer levels tends to decrease in soil organic carbon percentage.

Soil Nitrogen

The perusal of the data (Table 2) revealed that post-harvest soil nitrogen percentage tends to increase after the harvest of the crop as it was significantly affected by the application of both organic and inorganic nutrient input sources.

Amongst the different treatment combinations, the highest residual soil N was registered with application of 50% RDF along with poultry manure @ 2 t/ha + paddy straw @ 10 t/ha decomposed with waste decomposer solution (T_8) and it did not show any significant difference with rest of the treatments (T_2, T_3, T_4, T_5, T_6, T_7 & T_9) except with absolute control (T_1).

Soil Phosphorus

Data pertaining to post harvest soil phosphorus (table 2) revealed that post-harvest soil phosphorus percentage tends to increase after the harvest as it was significantly affected by the application of both organic and inorganic nutrient input sources.

The highest soil P_2O_5 was recorded with application of 50% RDF along with poultry manure @ 2 t/ha + paddy straw @ 10 t/ha decomposed with waste decomposer solution (T_8) and it was at par with the remaining treatments (T_2, T_3, T_4, T_5, T_6, T_7&T_9) except with control treatment (T_1).

Soil Potassium

The perusal of the data revealed that post-harvest soil potassium percentage tends to increase after the harvest as it was significantly affected by the application of both organic and inorganic nutrient input sources (table 2).

The application of 50% RDF + soil incorporation of biochar @ 2 t/ha along with vermicompost @ 4 t/ha(T_6) registered the highest soil K_2O and the rest of the treatments (T_2, T_3, T_4, T_5, T_7, T_8& T_9) did not show any significant variation with treatment (T_6) with respect to soil K_2O. Whereas, the significantly lowest soil K_2O was recorded in the absolute control (T_1).

After harvest of the sweet corn crop, the progressive increase in soil available N, P_2O_5 and K_2O observed as compared to the initial soil available nutrient status, might be due to addition of sizable quantities of organic nutrient input sources which in turn improves the soil fertility. Various organic sources such as poultry manure, vermicompost, biochar and paddy straw might aid in improving the soil nutrient status by increasing the microbial population in their respective treatments (Panchal *et al.*, 2018) [11]. In case of sole inorganic fertilizer treatment plots, the low available nitrogen status might be due to higher leaching losses when compared with organic and inorganic combination treatments.

Judicious combination of organic and inorganic mineral sources has been known to mutually reinforce the efficiency of both these sources, resulting in higher productivity in addition to maintenance of soil fertility over long period in an ecologically friendly manner.

Returns per rupee investment

The highest returns per rupee investment (2.71) was recorded with application of 100% RDF (T_2) which was significantly higher over all other nutrient management treatments. Among integrated nutrient management treatments, application of 75% RDF along with poultry manure @ 2 t/ha decomposed with waste decomposer solution (T_4) recorded highest returns per rupee investment(2.36) and it was on parity with various integrated nutrient management treatments having substitution of 25 to 50% RDF with different organic sources of nutrients (T_3,T_5, T_7 & T_9). Whereas the significantly lowest returns per rupee investment (0.78) was recorded in the absolute control (T_1). The minimum returns recorded with integration of organic sources which might be due to higher cost of vermicompost, and comparatively lower yields as reported by Jinjala *et al.* (2016) [9].

Table 1: Primary nutrient uptake, nitrogen use efficiency and returns per rupee investment of sweet corn as influenced by various organic and inorganic nutrient input sources.

Treatment details	Uptake of primary nutrients at harvest by Stover (kg/ha)			Nitrogen Use Efficiency		Returns per rupee investment
	N	P_2O_5	K_2O	Apparent N Recovery	Agronomic efficiency	
T_1: Control	23.43	12.13	62.03	-	-	0.78
T_2: 100% RDF (180-60-60 NPK Kg/ha)	70.27	23.60	125.23	0.73	43.39	2.71
T_3: 75% RDF + Biochar @ 2 t/ha + Vermicompost @ 2 t/ha	65.67	21.33	113.83	0.85	47.41	1.68
T_4: 75% RDF + Poultry manure @ 2 t/ha + Waste decomposer	67.70	21.77	115.20	0.90	48.01	2.36
T_5: 75% RDF + Paddy straw @ 10 t/ha + Waste decomposer.	65.33	21.00	113.00	0.85	45.76	2.21
T_6: 50% RDF + Biochar @ 2 t/ha + Vermicompost @ 4 t/ha	62.00	20.37	105.67	1.13	60.34	1.25
T_7: 50% RDF + Poultry manure @ 4 t/ha+ Waste decomposer	63.67	20.77	108.33	1.01	61.49	2.12
T_8: 50% RDF + Poultry manure @ 2 t/ha + Paddy straw @ 10 t/ha +Waste decomposer	59.67	20.33	105.00	1.08	59.54	1.90
T_9: 50% RDF +Biochar @ 1 t/ha +Paddy straw @ 10 t/ha + Poultry manure @ 2 t/ha +Waste decomposer	64.33	20.93	110.67	1.20	63.57	1.97
S Em ±	3.62	1.30	6.84	0.96	53.60	0.08
C.D (P=0.05)	10.8	3.91	20.5	-	-	0.26
C.V (%)	10.4	10.1	11.1	-	-	8.0

Table 2: Microbial population & soil fertility status after the harvest of sweet corn as influenced by various organic and inorganic nutrient input sources

Treatment details	Microbial population after harvest		Soil fertility status after the harvest (kg/ha)		
	Fungi CFU*10^{-4}	Bacteria CFU*10^{-6}	N	P_2O_5	K_2O
T_1: Control	12.17	4.17	132.00	12.27	203.53
T_2: 100% RDF (180-60-60 NPK Kg/ha)	8.73	3.67	251.00	18.67	281.67
T_3: 75% RDF + Biochar @ 2 t/ha + Vermicompost @ 2 t/ha	15.60	5.30	255.67	19.67	290.33
T_4: 75% RDF + Poultry manure @ 2 t/ha + Waste decomposer	26.23	6.77	253.67	19.33	294.33
T_5:75% RDF + Paddy straw @ 10 t/ha + Waste decomposer.	20.47	5.67	257.33	20.00	297.33
T_6: 50% RDF + Biochar @ 2 t/ha + Vermicompost @ 4 t/ha	19.03	7.54	263.67	20.77	308.00
T_7: 50% RDF + Poultry manure @ 4 t/ha+ Waste decomposer	32.03	9.23	261.00	20.50	302.67
T_8: 50% RDF + Poultry manure @ 2 t/ha + Paddy straw @ 10 t/ha +Waste decomposer	28.98	8.50	265.33	21.33	307.00
T_9: 50% RDF +Biochar @ 1 t/ha +Paddy straw @ 10 t/ha + Poultry manure @ 2 t/ha +Waste decomposer	32.00	9.20	259.00	20.33	299.67
S Em ±	1.03	0.46	13.38	1.11	13.3
C.D(P=0.05)	3.11	1.40	40.1	3.35	40.1
C.V (%)	8.3	10.6	9.6	10.3	8.1

Conclusion

Based on the present investigation it can be concluded that the highest returns per rupee investment was recorded with application of 100% RDF though there was low residual soil fertility and least microbial population observed. Among the integrated nutrient management treatments, application of 75% RDF along with poultry manure @ 2 t/ha decomposed with waste decomposer solution recorded highest returns per rupee investment and also improvement in residual soil fertility and microbial status.

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