



## Microbial inoculant enriched biochar and organic manures improve the productivity of sweet corn (*Zea mays*) and soil quality

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Sweet corn (*Zea mays* L. *saccharata*), an ear of specialty corn is gaining acceptance to fulfil the increasing needs of diversified sectors (Devi *et al.* 2018) as fresh grains, green cobs and green fodder. The fresh market accounts for nearly 74% of the value of the sweet corn crop and 26% of the processing market (Hu *et al.* 2021). In general, its productivity is low during the rainy (*khariif*) season due to many constraints, viz. non-availability of quality seeds, erratic weather conditions, poor drainage, poor nutrition, low nitrogen use efficiency (NUE), increased disease, pest attacks, difficulty in controlling weeds, poor stand establishment, etc. The use of inorganic fertilizers alone has ill effects on soil health. Apart from soil rehabilitation, there aren't many options for nitrogen management that go beyond conventional NPK fertilizers to increase productivity and efficiency (Njoroge *et al.* 2018). To maintain long-term nutrient release and availability to plants, reduce losses, and increase production levels, balanced nutrient management is required. Nutrients are used in a balanced manner to increase sweet corn yield and seed quality. Among organic sources, vermicompost (Purohit *et al.* 2020), poultry manure (Wailare *et al.* 2017), and biochar (Naeem *et al.* 2017) can have potential applications. Organic manures are generally required in huge quantities increasing the cost of cultivation and reducing returns. Therefore, an alternative organic source that is cheaper and more efficient can be very effective for successful integrated nutrient management. Biochar from agro-waste is carbon negative or climate-positive organic source that has unique properties, such as a porous structure, a large surface area, a large number of functional groups, recalcitrance, which allows for a large amount of carbon to be stored, and abundant mineral elements and the loading of fertilizer nutrients in the soil (Chaturvedi *et al.* 2021). As a result, it has a lot of potential as enriched compost for improving productivity,

and soil health, and preventing nutrient losses in soil and air. Biochar can prolong the thermophilic phase of the composting process, reduce ammonia, methane, and nitrous oxide emissions, and lower the pH of compost material (Singh *et al.* 2020). Combining biochar with fertilizers and organic sources improve the suitability of biochar materials for promoting plant development (Si *et al.* 2018). Compared to conventional organic sources, biochar may be more advantageous for maintaining soil fertility (Roy *et al.* 2021). Among inorganics, biochar-coated urea (BCU) is effective in reducing nitrogen losses during the *khariif* season and leads to increased growth parameters and yield. Thus, the present study was conducted to find the best combination of nutrient management practices for achieving higher growth and yield of sweet corn, as well as soil quality.

A field experiment was conducted during the rainy (*khariif*) season of 2020 at G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, in the Tarai region of the Himalayas. The sandy loam soil at the site was neutral (pH 7.1), with medium organic carbon (0.65%), low available N (178.77 kg/ha), P (21.7 kg/ha), and K (260.4 kg/ha). A composite soil sample (0–15 cm) was analyzed before sowing. The experiment, arranged in an RBD (randomized block design) with three replications, included eight treatments: T<sub>1</sub>, Control; T<sub>2</sub>, 100% RDF (recommended dose of fertilizer); T<sub>3</sub>, 100% RDF + VC (vermi-compost) @4 t/ha; T<sub>4</sub>, 100% RDF + EB (enriched biochar) @2 t/ha; T<sub>5</sub>, 75% RDF + VC @4 t/ha; T<sub>6</sub>, 75% RDF + EB @2 t/ha; T<sub>7</sub>, 75% RDF + VC @4 t/ha + micronutrient mixture and T<sub>8</sub>, 75% RDF + EB @2 t/ha + micronutrient mixture. EB was prepared using rice husk biochar, poultry manure, Trichoderma, biofertilizer, and cow dung slurry, with nitrogen supplied via biochar-coated urea.

EB and VC were applied to prepared fields before furrow opening. "CMVL Sweet corn-1" was sown at 10 kg/ha in a 60 cm × 20 cm spacing. Plant height and dry matter accumulation were recorded at 60 DAS, with five plants randomly measured for height and two for dry matter. Cobs were harvested at the soft dough stage, weighed without

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the husk, and cob yield was calculated. Green fodder yield was measured by cutting plants just below the soil surface. Organic carbon, nitrogen, phosphorus and potassium were analyzed using standard methods (Table 1). The benefit-cost ratio was calculated as net returns divided by total cultivation cost. Data were analyzed using OPSTAT software (Sheoran *et al.* 1998) with ANOVA at a 0.05 significance level, and CD values were used for mean comparisons.

Table 1 Characterization of enriched biochar and vermicompost-based fertilizers

Particular	Value of EB	Value of VC
Total C (%)	34.56	-
Total N (%)	2.57	1.2
Total P (%)	1.69	1.5
Total K (%)	1.6	1.5

EB, Enriched biochar; VC, Vermicompost.

The maximum plant height recorded under 100% RDF + EB @2 t/ha increased by around 51.3% as compared to 100% RDF alone at 60 DAS. It was also found significantly better than VC @4 t/ha at both levels 100% and 75% RDF (Table 2). Increased plant height was due to enhanced and sustained nutrient availability through EB and BCU under 100% RDF. Nitrogen uptake altered the plant cell size and fast elongation of internodes through increased photosynthesis, which led to increased plant height. Application of 100% RDF + EB also resulted in 53.5% greater total dry matter than 100% RDF alone and was comparable to T<sub>3</sub>, T<sub>6</sub>, and T<sub>8</sub>. The increase in periodic dry matter accumulation with the application of balanced fertilizer management may be attributed to an increase in plant height and leaf area index resulting in a better light interception by the crop, which accumulated more photosynthates and produced more dry matter production. Similar findings on the increased dry weight of maize were reported by Kazemi *et al.* (2019) and Shakunthala *et al.* (2018).

The application of biochar had a positive influence on

growth, resulting in heavier cobs through better nutrient supply and manoeuvring soil properties. The findings are consistent with those of Sonpure *et al.* (2015). There was a marked increase in husked and green fodder yield under the 100% RDF + EB application and significantly higher yield increments were recorded. The de-husked yield was found highest in 100% RDF + EB because of more de-husked cob weight and no. of grains/cob, cob length, and cob girth was also better which influenced cob weight. Application of 100% RDF + EB resulted in better plant growth and development by providing balanced nutrition, enhanced nutrient availability, and better chlorophyll synthesis, which helped in the assimilation and translocation of photosynthates supported by Mithare *et al.* (2019) and Alubiagba *et al.* (2021). A similar trend was followed by green fodder yield. The increased green fodder yield under 100% RDF + EB was due to more plant height which gives more green fodder yield as compared to other treatments. The yield was increased proportionately to growth parameters due to enriched biochar with organics that had more nutrients than VC (Naveena *et al.* 2021) and better and sustained nitrogen availability through slow-release BCU.

In comparison to 100% RDF, the application of 100% RDF + EB @2 t/ha increased soil organic carbon by 10.7% (Table 3), but was unable to significantly increase the soil's organic carbon content in a single growing season. However, different treatments had a considerable impact on the nutrients available in the soil. The maximum N and P were recorded in 100% RDF + EB, which was 2.6 and 4.3% greater than 100% RDF, respectively. The usage of biochar, which has a large surface area, a lot of mesopores and micropores, a stable adsorption capacity throughout a wide pH range, and good selective adsorption when ions, humic acid, and pore volume are present, contributes significantly to the improvement of soil quality. Additionally, it aids in stimulating the colonization of mycorrhizal roots, which increases nutrient intake by increasing root surface area (Javeed *et al.* 2022). Soil physicochemical characteristics were greatly enhanced by reducing bulk density and

Table 2 Plant height, dry matter, and yield of sweet corn influenced by different treatments

Treatments	Plant height (cm)	Dry matter	Husked cob yield	De-husked cob	Green fodder
	60 DAS	(g/plant) 60 DAS	(t/ha)	yield (t/ha)	yield (t/ha)
T <sub>1</sub> , Absolute control	72.9	13.67	4.35	3.27	6.72
T <sub>2</sub> , 100% RDF	123.9	29.67	9.79	6.88	13.47
T <sub>3</sub> , 100% RDF + VC @4 t/ha	183.0	32.17	11.18	7.73	15.91
T <sub>4</sub> , 100% RDF + EB @2 t/ha	187.5	35.30	12.06	8.65	17.64
T <sub>5</sub> , 75% RDF + VC @4 t/ha	136.9	30.35	9.47	6.68	12.44
T <sub>6</sub> , 75% RDF + EB @2 t/ha	163.0	26.58	10.70	7.50	15.03
T <sub>7</sub> , 75% RDF + VC @4 t/ha + $\mu$ NM	140.0	28.21	9.70	6.88	13.77
T <sub>8</sub> , 75% RDF + EB @2 t/ha + $\mu$ NM	163.0	29.65	10.88	7.62	15.60
SEM $\pm$	24.4	1.96	0.53	0.46	0.87
CD (5%)	8	5.94	1.60	1.40	2.63

RDF, Recommended dose of fertilizer (150:80:60); EB, Enriched biochar; VC, Vermicompost;  $\mu$ NM, Micronutrient mixture.

Table 3 Soil chemical characteristics and B:C ratio of sweet corn influenced by different treatments

Treatments	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	B:C ratio
T <sub>1</sub> , Absolute control	0.64	167.1	21.9	262.9	1.44
T <sub>2</sub> , 100% RDF	0.65	182.8	22.8	275.0	2.58
T <sub>3</sub> , 100% RDF + VC @4 t/ha	0.69	186.9	23.0	280.0	1.84
T <sub>4</sub> , 100% RDF + EB @2 t/ha	0.72	187.7	23.8	279.1	2.89
T <sub>5</sub> , 75% RDF + VC @4 t/ha	0.66	183.4	22.2	277.0	1.56
T <sub>6</sub> , 75% RDF + EB @2 t/ha	0.70	184.7	23.9	275.8	2.55
T <sub>7</sub> , 75% RDF + VC @4 t/ha + $\mu$ NM	0.68	183.6	22.4	277.6	1.55
T <sub>8</sub> , 75% RDF + EB @2 t/ha + $\mu$ NM	0.70	184.6	23.5	275.5	2.46
SEM $\pm$	0.01	1.3	0.4	2.0	0.21
CD (5%)	NS	4.1	1.13	6.1	0.64

RDF, Recommended dose of fertilizer (150:80:60); EB, Enriched biochar; VC, Vermicompost;  $\mu$ NM, Micronutrient mixture.

increasing porosity, moisture retention, organic matter content, percentage nitrogen, and accessible phosphorus (Shi *et al.* 2022).

Similar to this, our findings showed that organics improved soil quality parameters when compared to inorganics alone. With regard to organic carbon, N, P, and K among the organic components, EB enhanced soil characteristics; however, it was at par with VC @4 t/ha. Due to biochar's increased surface charge and capacity to store cationic compounds, which aid in storing nutrients until they reach maturity (Siddika *et al.* 2022) micronutrients was added to the soil in VC and EB, where it was shown that the micronutrient response was higher with 100% RDF + EB than with VC. When compared to other treatments, 100% RDF + EB had the highest benefit-cost ratio. This makes sense for farmers when compared to other organics and inorganics.

Hence, it can be concluded that the addition of 100% RDF + EB @2 t/ha recorded the highest growth, yield and better economics due to cheaper cost and lower application rate of EB. Enriching biochar with microorganism inoculants and organics can be effective organic source for yield enhancement and soil improvement.

#### SUMMARY

The study assessed the effects of different fertilizers on balanced nutrition in sweet corn (*Zea mays* L. *saccharata*) and was conducted during the 2020 rainy (*khariif*) season. According to the results, applying 100% RDF + EB @2 t/ha produced the highest plant height and dry matter at 60 days, which was similar to applying 100% RDF + VC @4 t/ha. When compared to 100% RDF alone, the yield of husked cobs increased by 23.18% with the 100% RDF + EB @2 t/ha treatment. Similarly, 75% RDF + EB @2 t/ha and 75% RDF + EB @2 t/ha + micronutrient mixture improved yield by 9.29% and 11.13%, respectively. Enriched biochar improved soil quality, including higher levels of available N, P, K and organic carbon, compared to 100% RDF alone. The study recommended using enriched biochar with 100% RDF for quality sweet corn production in Mollisols.

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