Seaweed and its role in enhancing yield and antioxidant properties in sweet corn

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Abstract

Nutrient management plays a crucial role in the yield and quality of sweet corn. A field experiment was conducted during the years 2018 and 2019 to investigate the effect of organic and standard sources of fertilizer on the yield and quality of sweet corn within the new soil of West Bengal, India. The organic sources (OS) of fertilizer were vermicompost (VC), (Ascophyllum nodosum) Soligro granular (OS1), Bioenzyme liquid (OS2), and Opteine (Ascophyllum nodosum) filtrate (OS3). The traditional input was chemical fertilizer (CF) applied at the recommended dose of 150:75:75 kg ha-1 of N: P2O5:K2O for the sweet corn. The organic source VC was wont to supply 100% N recommendation as one source or 50% N recommendation when combined with CF or organic sources. Maximum fruit yield was recorded when recommended dose of Fertilizer (RDF) CF was applied at full dose, which was on a par with 50% recommended dose of chemical fertilizer together with 50% recommended dose of vermicompost on a nitrogen equivalent basis and VC at the total recommendation. A better percentage of large-size cob (> 25 cm) was obtained in VC-based treatments compared with CF treatment. Vermicompost at full dose increased antioxidant, carotenoid, and phenol content compared with its half dose together with other sources. The potential exists to enhance sweet corn cob quality through better nutrient management, whether or not it's conventional, organic, or a mix of both.

Introduction

As we are moving towards civilization, food security, food safety, and feeding to the subsequent generation could be a big question. From that long-term perspective, we will depend upon sustainable agriculture. Low soil fertility is one of ever of the bottlenecks to sustaining agricultural production and productivity (Negassa et al., 2007). Restoration and scientific management of land productivity are the keys to achieving yield maximization of crops and sustainable development in agriculture. In intensive cropping, the provision of appropriate sources and amounts of nutrients is indispensable for yield maximization. In conventional practices, improved cropping systems related to high-value crops depend on the utilization of chemical fertilizer because of its immediate availability of nutrients to the plants. Indiscriminate and continuous use of such chemical fertilizers results in instability in yield and also poses a threat to soil health particularly because of micronutrients deficiency and fertilizer-related environmental pollution (Prasad and Power, 1995). Moreover, it should raise an issue about the standard and acceptability of the merchandise within the market.

Organic fertilizers are mainly derived from animal and plant residues which contain plant nutrients in complex organic forms. Organic fertilizer provides not only primary nutrients but also makes available the micronutrients besides improving soil physical properties. Nutrient release patterns from organic fertilizers are slow and steady than that of chemical fertilizers and are stored for longer periods in the soil, thereby ensuring a long residual effect (Sharma and Mittra 1991). To meet the nutrient demand of crop, organic fertilizers are, however, required in rather large quantities which make for strong advocacy for fortifying these manures with inorganic fertilizers. There are ample shreds of evidence that under integrated nutrient management, nitrogenous chemical fertilizer accelerates the pace of mineralization by lowering the wide C: N ratio of organic matter rich in carbon and low in nitrogen. Sustainable yield levels could be achieved by applying an appropriate combination of organic manures and chemical fertilizers (Sujatha *et al*., 2008).

Biostimulants are an emerging class of crop management products that target the modulation of crop stress to increase productivity. Several definitions of a biostimulant have been proposed and reviewed (Yakhin *et al*., 2017). The European Biostimulant Industry Consortium (EBIC) is leading the international marketplace in defining and seeking regulation for biostimulant products in Europe. EBIC has defined biostimulant as “containing substance(s) and/or microorganisms whose function when applied to plants or the rhizosphere is to stimulate natural processes to enhance/benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and crop quality. du Jardin (2015) assigned biostimulants into 8 categories: (i) humic substances, (ii) complex organic materials, (iii) beneficial chemical elements, (iv) inorganic salts, (v) seaweed extracts, (vi) chitin and chitosan derivatives, (vii) antitranspirants and (viii) free amino acids and other N containing substances with microorganisms a potential ninth category.

Seaweed extracts are prominent within the biostimulant market, representing the fastest-growing biostimulant product category (du Jardin, 2015). The consequences of seaweed extracts on plants are reviewed (Craigie, 2011; Sharma et al., 2014) with a variety of biostimulant effects reported, including drought tolerance. It’s important to acknowledge that seaweed extract biostimulants aren't a uniform category of products. Seaweed extract biostimulants vary looking on the seaweed species used for manufacture (e.g. brown, green or red), the spatiotemporal source of the seaweed staple, and therefore the process used for manufacture/extraction (Khan et al., 2009; Sharma et al., 2014). Most of the commercial seaweed extracts with biostimulant effects are manufactured with brown algal species, with Ascophyllum nodosum the dominant species because of its long history of positive ends up in enhancing crop productivity (Craigie, 2011). Ascophyllum nodosum extract (ANE) biostimulants have previously been reported to extend drought stress tolerance of grasses and crops (Spann and Littele, 2011 and Elansary et al., 2017).

Sweet corn (Zea mays L. saccharata) could be a hybridized style of maize (Zea mays L.) specifically bred to extend the sugar content also called maize. Sweet corn is that the style of corn with a skinny pericarp layer, the translucent, horny appearance of kernel when matured and wrinkled when dries. Total sugar content at milky stage ranges 25–30% compared to normal corn 2–5%. The crop is harvested at the tender stage and consumed within the immature stage of the crop. Sweet corn is one of the popular vegetables within the USA, Canada, and Australia and it's gaining acceptance as a frozen vegetable. It’s becoming popular in India and other Asian countries. Sweet corn may be a highly nutritive crop, in keeping with a study per 100 gm of sweet corn contains 19.02 gm carbohydrates, 2.70 gm dietary fiber, 1.18 gm fat, and 3.2 gm protein. It’s rich in thiamin, vitamin B5, Vitamin C, folate, phosphorus, dietary fiber, and manganese and may be a good source of phenolic, flavonoid, antioxidant, and ferulic acid. Several research studies suggest that ferulic acid plays an important role in preventing cancers, aging, and inflammation in humans. Being a short-duration crop farmers can grow it twice in a very year depending upon the agro-climatic conditions and also a substitute in times of failure. Sweet corn may be a high-value and heavy feeder crop, nutrient management is taken into account to be a very important aspect. Nutritional status at harvest and a post-harvest lifetime of crops are very important to consider in terms of grain quality. The necessity to extend productivity moreover as maintain sustainability, the introduction of fertilizer is worldwide.

Materials And Methods

Site characteristics

The field experiment was conducted during the wet season (Kharif season) of 2018 and 2019 to study the "nutrient management for growth, yield and quality of sweet corn (*Zea mays var. sachharata*) in the new alluvial soil of West Bengal" at C block farm, Kalyani under B.C.K.V., Nadia, West Bengal. It is situated at 22˚57" N latitude and 88˚2" E longitude with an altitude of 9.75 meters above the mean sea level (MSL). The farm is situated in the New Alluvial Zone of West Bengal under the subtropical climate with characteristics of high summer temperature, erratic rainfall, high humidity, and short-mild winter. The long-term average annual rainfall is about 1396 mm. During the experimental period (2018-2019), the annual rainfall received was in the range of 1.5 to 405.9 mm and 0 to 108.8 mm respectively. The average maximum temperature varied from 24.5 to 35.4^{0}C (2018), 25.3 to 36.1^{0}C (2019) and the mean minimum temperature varied from 11.7 to 27.2^{0}C (2018), 13.9 to 27.1^{0}C (2019). The average maximum and minimum relative humidity ranged from 89.5 to 95.2 (2018), 87.5 to 91.6 (2019), and 39.9 to 80.5 (2018), 46.8 to 71.8 (2019) percent respectively. The average daily sunshine hour varied from 4 to 7.5 (2018), 3.4 to (2019) hours per day (Fig. 1).

The experiment was laid out in Randomized Block Design (RBD) having three replications and each replication having eight treatments.T_1: Control plot, T_2: RDF $CF_{100\%}$ (150:75:75 kg ha^{-1}), T_3: $RDNVC_{100\ \%}$ (7.5 t $ha^{-1)}$, T_4: $RDNCF_{50\ \%}$ + RDN $VC_{50\ \%}$ (3.75 t ha^{-1}), T_5: RDN $CF_{50\ \%}$ + RDN $OS1_{50\ \%}$ (10 kg ha^{-1}), T_6: RDN $CF_{50\ \%}$ + RDN $OS2_{50\ \%}$ (625 ml ha^{-1}), T_7: RDN $CF_{50\ \%}$ + RDN $OS3_{50\ \%}$ (625 ml ha^{-1}), T_8: RDN $VC_{50\ \%}$ (3.75 t ha^{-1}) + RDN $OS1_{50\ \%}$ (10 kg ha^{-1}).

Sweet corn variety Sugar-75 was used as a planting material, which is a potent hybrid variety of sweet corn. The texture of the experimental soil was sandy clay loam and belongs to the order Entisol, medium in texture, low available nitrogen, high phosphorus, medium potassium, and high sulfur content. The experiment was conducted under the medium land situation. Physico-chemical properties of the experimental plots are given (Table1).

The chemical fertilizer was applied through urea, single super phosphate, and muriate of potash. The organic source VC was used to supply 100% N recommendation as a single source or 50% N recommendation when combined with conventional input or organic sources. Seaweed extract was applied as organic sources as OS1: Soligro (*Ascophyllum nodosum*) granular, OS2: Bioenzyme (liquid), and OS3: Opteine (*Ascophyllum nodosum*) filtrate. The chemical composition of both vermicompost and seaweed extract is given in (Tables 2 and 3).

Cob yield

The cobs were removed from the plants of 1 m^2 per plot and taken the total fresh cob yield of 1 m^2 and using this fresh cob yield was worked out and expressed in kg per ha.

Quality Analysis

After harvesting, cobs were weighed to record yield and the samples were prepared for quality analysis. Grains were removed, blended with a homogenizer, and filtered through gauze to remove skin and membranes. Sweet corn slurry was prepared and kept in plastic bags separately replication and treatment wise each containing 10-20 g. The bags were sealed and immediately stored at -70^{o}C for subsequent analysis of sweet corn quality parameters such as total sugar, total soluble solids (TSS), carbohydrate, protein, ascorbic acid, carotenoid, and phenol.

Quality parameter

Immediately after harvest, the cobs are passed through grading plates of known diameter. The fruits are graded into five different sizes: 25 cm, 25–20 cm, 20–15 cm, 15–10 cm, and 10 cm. Total sugar content was determined following Lane and Eynon method as per Sadasivam and Manickam (1996). The total soluble solids (TSS) in sweet corn grain were analyzed at the milky stage of sweet corn by using a hand refractometer and expressed in percentage. The total carbohydrate content of sweet corn grain was estimated by the phenol sulphuric acid method as suggested by (Krishnaveni *et al.,* 1984). Total N content in sweet corn grain was determined by the wet digestion method in modified micro Kjeldahl (Piper, 1966). Then the protein content in the grains of individual treatment was calculated by multiplying the nitrogen content (%) in the grains by the factor 6.25 and expressed in percentage. The beta-carotene content was estimated by the spectrophotometric method as per Sadasivam and Manickam (1996). The determination of total ascorbic acid was done based on coupling 2,4- dinitrophenyl hydrazine (DNPH) with the ketonic groups of dehydroascorbic acid through the oxidation of ascorbic acid by 2,6-dichlorophenolindophenol (DCPIP) to form a yellow-orange color in acidic conditions (Pelletier, 1985). Total phenol content was determined spectrophotometrically as per Malick and Singh (1980).

Seaweed extracts

Seaweed extracts (*Ascophyllum nodosum*) extract based organic granular product for soil application. SoliGro GR is a soil health product powered by Acadian Bio Switch bioactive compound which enhances natural processes within soil resulting in root development, microbial activity, soil conditioning, plant growth, and helps protect crops against environmental stresses. It is a soil health product containing an exclusive mixture of beneficial bioactive compounds such as polysaccharides, organic acids that invigorate the soil environment, particularly by promoting the activities of beneficial soil micro-organisms. SoliGro GR provides balanced nutrition for optimum growth, yield, and quality, it helps plants to overcome abiotic environmental stresses like drought, salinity, cold, and frost efficiency and finally, boosts the immune system of the plants.

Statistical Analysis

The effect of treatments was evaluated by standard procedures as described by Gomez and Gomez (1984). Analysis of variance was performed using the program SPSS 11.0 for windows. Significantly, different means were separated at a 0.05%probability level by Duncan's Multiple Range Test (DMRT).

Result

Cob yield

Cob yield of sweet corn is presented in Table 4. The maximum yield was noted in an entire dose of recommended chemical fertilizer (T2) which was at par with 50% recommended dose of chemical fertilizer along with 50% recommended dose of vermicompost on nitrogen equivalent basis (T4) and RDNVC100% during both the year. Application of full dose of fertilizer through chemical sources recorded 0.37% yield increment, whereas the full dose of fertilizer through vermicompost recorded 1.21% yield increment and integration of chemical and vermicompost recorded 0.80% yield increment from the first year to the second year. It is noted that the application of nutrients through the suboptimal dose of chemical fertilizer with seaweed extract always produced a lower yield than a full dose of nutrients either through the sole application of organic and inorganic or their integration.

Cob size

The different sizes of harvested sweet corn cob under different nutrient management are shown in Figure 2. The maximum proportion of the fruit size was highest within the RDN $VC_{100\%}$ treatment followed by RDN $VC_{50\%}$ + RDN $CF_{50\%}$ and RDF $CF_{100\%}$ treatment. Control treatment produced the next percentage of smaller size cobs (10-15 cm) during the first year. However, in the second year, RDN $VC_{50\%}$ +OS1 treatment produced the next percentage of large-size fruits.

At the half dose of chemical fertilizer through nitrogen along with the organic source, a higher percentage of large-size cobs were noted, particularly in the RDN $VC5_{0\%}$ +OS1 treatment.

Quality Parameter

Application of different organic and inorganic fertilizer sources and their combinations on quality parameters total sugar content (%), TSS (0Brix), total Carbohydrate (%), Protein (%), Carotenoid (mg/100g), Ascorbic acid (mg g^{-1}), Phenol (mg/100g) of sweet corn indicated that all the quality parameter differ significantly except protein content during 2018 (Table 6 and 7).

The sugar content of sweet corn under different fertilizer treatments varied from 13.53 to 19.56 % during 2018 and 11.39 to 19.77 % during 2019. Maximum sugar content was obtained when 50% recommended dose of chemical fertilizer along with 50% of the recommended dose of soligro in nitrogen equivalent basis (i.e. T_5 treatment) which is at par with an entire dose of recommended chemical fertilizer (T_2 treatment).

Total Soluble Solid content varied from 7.70 to 17.57^{0}Brix in 2018 and 8.03 to 17.87^{0}Brix in 2019. The highest TSS value was observed in an entire dose of recommended chemical fertilizer (T_2) treated plot which showed significantly superior to other treatments.

Maximum carbohydrate content 23.35% and 23.39 % during 2018 and 2019 respectively was observed when 50% recommended dose of chemical fertilizer along with 50% recommended dose of vermicompost in nitrogen equivalent basis (T_4 treatment) is applied which was at par with $RDFCF_{100\%}$ (T_2 treatment).

The maximum protein content of 13.18 and 13.23 % was recorded by $RDFCF_{100\%}$ (T_2) during 2018 and 2019 respectively which was superior to other treatments and at par with RDN $CF_{50\%}$ + RDN $VC_{50\%}$ (T_4 treatment).

Carotenoid content was found highest 0.55 mg/100g during 2018 while during 2019 highest carotenoid content of 0.61 mg/100g was found in RDN $VC_{100\%}$ (T_3) treatment which was at par with $RDFCF_{100\%}$ (T_2) treatment.

The ascorbic acid content of sweet corn under different fertilizer treatments varied from 1.55 to 8.35 mg g^{-1}during 2018 and 1.49 to 8.45 mg g^{-1}during 2019. Maximum ascorbic acid content was obtained when the entire dose of recommended vermicompost was applied (T_3), which was found significantly superior to other treatments.

The total phenol of sweet corn under different fertilizer treatments varied from 40.24 to 54.97 mg per 100g during 2018 and 40.58 to 55.06 mg per 100 g during 2019. The optimal dose of fertilizer supplied either through chemical or organic sources produced higher phenolic than at suboptimal dose or control treatments. Maximum phenol was recorded by RDF $CF_{100\%}$ treatment application in both years. Similar trends were followed in pooled data obtained from statistical analysis.

Discussion

The full dose of either chemical fertilizer and vermicompost or their combined application was found superior in yield and quality than the applying of chemical fertilizer at suboptimal dose together with seaweed extracts. the speed of mineralization differed from chemical fertilizer thereto of organic ones. Nutrient released by chemical fertilizer is instantly available to plants, therefore the immediate response is observed in crops. Whereas, in organic one long-term effect has been seen. it's also observed that over the year the difference of yield between the complete and suboptimal dose of fertilizer through organic and/or chemical sources is getting narrower. the very best cob yield of those treatments could be because of the utmost yield component in these treatments. Present results support the previous study of Reed et al., (1988). Besides supplying both macro and micronutrients, vermicompost releases plant growth regulators, humic acid, and humus colloids hold nutrient cations (K^+, Ca^{2+}, Mg^{2+}, etc.) in an easily exchangeable form, wherein they will be employed by plants but not too readily leached out from profile by percolating water. Organic acid, polysaccharides, and humic substances all can attract such cations as Fe^{3+}, Cu^{2+}, Zn^{2+}, and $Mn^{2+}$from the sides of mineral structures and chelate or bind them in stable organo-mineral complexes (Brady and Weil, 2002). Satisfying the complete dose through the combined application of chemical and vermicompost was also found equally promising in supplying nutrient elements in the available form to a rapid release from chemical sources furthermore as slow and steady from organic sources within the soil together with essential micronutrients and growth-promoting substances. Paramanathan (2000) revealed that integrated nutrient management by complementary use of chemical fertilizer and compost seems to be the simplest to improve corn yield.

In this experiment, the applying of a full dose of fertilizer produced more cobs than suboptimal or no fertilizer application. Higher levels of obtainable nutrients within the soil and their greater uptake may need to be accountable for the increased number of sweet corn cobs of larger size, thereby increasing yield when a full dose of fertilizer was applied through organic and/or chemical sources compared with no fertilizer application. Large size tomato fruits were also reported when grown organically (Doan et al., 2015).

The higher crude protein content of chemically fertilized crops was associated with higher nitrogen availability in soil from the chemical fertilizer and thereby, greater N uptake by crop which, plays an important role in the synthesis of nucleic acid and protein. A similar finding was also reported by Lockeretz *et al.,* (1981) and Magkos *et al.,* (2003) who observed higher crude protein in conventionally grown sweet corn than the organic one. The experimental finding reveals that a full dose of fertilizer and/or the suboptimal dose of chemical along with vermicompost increased sugar content (Table 5). Arun Kumar *et al.,* (2007) reported that application of 100% Recommended Dose of Phosphorus (RDP) along with either 75%or 100% RDN of grain maize increased reducing sugar, non-reducing sugar, and total sugar. The major secondary metabolites of sweet corn are ascorbic acid and total phenolics. According to C/N balance theory, when inorganic fertilizers are applied N is readily available to plants, will primarily make compounds with high N content (e.g protein for growth), while organic fertilizers are applied N availability is limited due to slow-release plant metabolism changing more towards carbon-containing compounds such as starch, cellulose, and non-N containing secondary metabolites such as phenolics and terpenoids (Haukioja *et al*., 1998). Organically produced crops contain more ascorbic acid than conventional crops (Asami *et al.*, 2003).

Higher carotenoid content either through the full dose of vermicompost or seaweed and their combination might be due to contribution of both macro and micronutrient slowly and steadily to the soil and thereby, their greater uptake in the plant. Micronutrients like Cu, Mn, and Zn play a significant role in metabolic processes and act as a cofactor of antioxidant enzymes has been reported by Grotz and Guerinot (2006).

Conclusion

All the treatments recorded promising results through the application of a full dose of fertilizer through chemical sources or combination with vermicompost resulted in a higher yield of sweet corn as compared to other treatments. Vermicompost-based treatments were most promising in improving the quality of sweet corn through increasing carbohydrate %, carotenoid, ascorbic acid, and total phenolics content than chemical fertilizer. Besides that *Ascophyllum nodosum* extract increases total sugar and TSS content.

The combined application of organic and chemical fertilizer satisfying the nutrient requirement of the crop is recommended for maintenance of the crop yield with better quality as compared to the application of only chemical fertilizer.

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Declarations

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Data Availability Statement Supplementary data associated with this article can be found in the online version of the manuscript.

Tables

Table 1: Physio-chemical properties of the experimental soil

Particulars	Results	Analytical methods employed
Mechanical composition		International Pipette Method
Sand (%)	54.8	
Silt (%)	21.75	
Clay (%)	23.45	
Bulk density(g cc^{-1})	1.31	
Soil texture	Sandy clay loam	USDA system
Electrical conductivity of EC (dsm^{-1})	0.51	Conductivity bridge method
Soil pH	7.04	Beckman's pH meter method
Organic carbon	0.45	Walkley and black's rapid titration method
Available N (kg ha^{-1})	188.9	Alkaline permanganate (Subbiah and Asija ,1956)
Available P (kg ha^{-1})	39.35	$NaHCO_3$-Extraction (Jackson, 1973)
Available K (kg ha^{-1})	184.70	NH_4OAc- Extraction (Jackson, 1973)
Available S (kg ha^{-1})	53.38	Chesnin and Yien (1950)
Available Zn mg kg^{-1}	2.56	DTPA extracts (Lindsay and Norvell, 1978)
Available Fe mg kg^{-1}	74.45	DTPA extracts (Lindsay and Norvell, 1978)
Available Mn mg kg^{-1}	20.75	DTPA extracts (Lindsay and Norvell, 1978)
Available Cu mg kg^{-1}	1.465	DTPA extracts (Lindsay and Norvell, 1978)

Table 2: Nutrient compositions of Seaweed extract (*Ascophyllum nodosum*)

Constituents	Concentration
Water (%)	70-85
Ash	15-25
Alginic acid	15-30
Laminaran	0-10
Mannitol	5-10
Fucoidan	4-10
Carbohydrates	10
Protein	5-10
Fat	2-7
Tannins	2-10
K	2-3
Na	3-4
Mg	0.5-0.9
Iodine	0.01-0.1
Cu (µg g^{-1} of extract)	8.64
Mn (µg g^{-1} of extract)	8.75
Zn (µg g^{-1} of extract)	19.92
Fe (µg $g^{-1}$of extract)	858.50

*All figures, except for water (%), are given as g 100 g^{-1} of dry matter.

References: Baardseth (1970), Aslam*et al.,* 2010

Table 3: Nutrient composition of vermicompost analyzed in laboratory

Nutrient	Content
N (%)	2.1 – 2.6
P (%)	1.5 – 1.7
K (%)	1.4 – 1.6
Organic carbon (%)	9.15 to 17.98
Ca (mg kg^{-1})	2760
Mg (mg kg^{-1})	4100
Available S (mg kg^{-1})	128 to 548
Copper (mg kg^{-1})	100
Iron (mg kg^{-1})	1800
Zinc (mg kg^{-1})	50

Table 4: Effect of fertilizer sources on sweet corn cob yield (t ha^{-1}) during 2018 and 2019

Treatments	Yield (t/ha)		
	2018	2019	Pooled
T_1: Control	4.28^{c}	4.31^{c}	4.30^{c}
T_2: RDF $CF_{100\%}$	10.75^{a}	10.79^{a}	10.77^{a}
T_3: RDN $VC_{100\%}$	8.22^{abc}	8.32^{abc}	8.27^{abc}
T_4: RDN $CF_{50\%}$ + RDN $VC_{50\%}$	9.92^{ab}	10.00^{ab}	9.96^{ab}
T_5: RDN $CF_{50\%}$ + RDN $OS1_{50\%}$	6.30^{bc}	6.67^{abc}	6.48^{bc}
T_6: RDN $CF_{50\%}$ + RDN $OS2_{50\%}$	6.41^{bc}	6.59^{abc}	6.50^{bc}
T_7: RDN $CF_{50\%}$ + RDN $OS3_{50\ \%}$	6.53^{bc}	6.86^{abc}	6.70^{bc}
T_8: RDN $VC_{50\%}$ + RDN $OS1_{50\ \%}$	5.31^{c}	5.48^{bc}	5.40^{c}

The means followed by the same letters are not significantly different at $p < 0.05$ level.

RDF: Recommended dose of Fertilizer, CF: Chemical Fertilizer, VC: Vermicompost, OS1: Soligro (*Ascophyllum nodosum*) granular,
OS2: Bioenzyme (liquid), OS3: Opteine (*Ascophyllum nodosum*) filtrate

Table 5: Effect of fertilizer sources on Total sugar content (TSS), Carbohydrate and Protein content of sweet corn during 2018 and 2019

Treatments	Total sugar (%)			TSS (^{0}Brix)			Carbohydrate (%)			Protein (%)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1: Control	13.53^{d}	11.39^{d}	12.46^{d}	7.70^{e}	8.03^{e}	7.87^{c}	10.97^{c}	11.30^{d}	11.13^{d}	9.45^{b}	9.65^{c}	9.55^{b}
T_2: RDF $CF_{100\%}$	19.56^{a}	19.77^{a}	19.66^{a}	11.45^{d}	11.33^{d}	11.39^{c}	22.13^{a}	22.37^{a}	22.25^{a}	13.18^{a}	13.23^{a}	13.20^{a}
T_3: RDN $VC_{100\%}$	15.13^{bcd}	16.61^{bc}	15.87^{bc}	14.50^{b}	14.73^{bc}	14.62^{ab}	18.27^{b}	18.53^{bc}	18.40^{bc}	9.70^{b}	9.91^{c}	9.80^{b}
T_4: RDN $CF_{50\%}$ + RDN $VC_{50\%}$	15.84^{bc}	18.18^{ab}	17.01^{abc}	14.90^{b}	15.20^{b}	15.05^{ab}	23.35^{a}	23.39^{a}	23.37^{a}	11.96^{ab}	12.17^{ab}	12.06^{ab}
T_5: RDN $CF_{50\%}$ + RDN $OS1_{50\%}$	19.33^{a}	19.62^{a}	19.48^{a}	13.87^{bc}	14.20^{bc}	14.03^{ab}	17.97^{b}	18.10^{c}	18.03^{c}	9.34^{b}	9.69^{c}	9.51^{b}
T_6: RDN $CF_{50\%}$ + RDN $OS2_{50\%}$	14.39^{cd}	14.69^{c}	14.54^{cd}	17.57^{a}	17.87^{a}	17.72^{a}	18.63^{b}	18.97^{bc}	18.80^{bc}	9.53^{b}	9.78^{c}	9.65^{b}
T_7: RDN $CF_{50\%}$ + RDN $OS3_{50\ \%}$	16.70^{b}	17.47^{ab}	17.08^{abc}	12.83^{cd}	13.13^{c}	12.98^{ab}	17.99^{b}	18.32^{bc}	18.15^{bc}	9.55^{b}	10.05^{c}	9.80^{b}
T_8: RDN $VC_{50\%}$ + RDN $OS1_{50\ \%}$	17.13^{b}	17.70^{ab}	17.42^{ab}	15.10^{b}	15.43^{b}	15.27^{ab}	20.65^{ab}	21.32^{ab}	20.99^{ab}	10.50^{ab}	10.81^{bc}	10.65^{b}

The means followed by the same letters are not significantly different at $p < 0.05$ level.

RDF: Recommended dose of Fertilizer, CF: Chemical Fertilizer, VC: Vermicompost, OS1: Soligro (*Ascophyllum nodosum*) granular,
OS2: Bioenzyme (liquid), OS3: Opteine (*Ascophyllum nodosum*) filtrate

Table 6: Effect of fertilizer sources on Carotenoid, Ascorbic acid and Phenol content of sweet corn during 2018 and 2019

eatments	Carotenoid (mg/100g)			Ascorbic acid (mg g^{-1})			Phenol (mg/100g)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
: Control	0.36^{d}	0.37^{b}	0.37^{c}	1.55^{d}	1.49^{d}	1.52^{d}	40.24^{d}	40.58^{e}	40.41^{e}
: RDF $CF_{100\%}$	0.55^{ab}	0.56^{a}	0.56^{a}	3.89^{b}	3.96^{b}	3.93^{b}	51.27^{ab}	51.35^{ab}	51.31^{ab}
: RDN $VC_{100\%}$	0.59^{a}	0.61^{a}	0.60^{a}	8.35^{a}	8.45^{a}	8.40^{a}	54.97^{a}	55.06^{a}	55.02^{a}
: RDN $CF_{50\%}$ + RDN $C_{50\%}$	0.52^{abc}	0.54^{a}	0.53^{ab}	4.60^{b}	4.70^{b}	4.65^{b}	49.28^{abc}	49.32^{bc}	49.30^{abc}
: RDN $CF_{50\%}$ + RDN $S1_{50\%}$	0.42^{bcd}	0.43^{b}	0.43^{bc}	2.34^{cd}	2.44^{cd}	2.39^{cd}	43.27^{cd}	43.31^{de}	43.29^{de}
: RDN $CF_{50\%}$ + RDN $S2_{50\%}$	0.39^{cd}	0.40^{b}	0.39^{c}	2.52^{cd}	2.58^{c}	2.55^{cd}	44.49^{cd}	44.83^{cde}	44.66^{cde}
: RDN $CF_{50\%}$ + RDN $S3_{50\%}$	0.40^{cd}	0.41^{b}	0.41^{bc}	2.81^{c}	2.90^{c}	2.86^{c}	48.12^{bc}	48.46^{bcd}	48.29^{bcd}
: RDN $VC_{50\%}$ + RDN $S1_{50\%}$	0.57^{a}	0.58^{a}	0.57^{a}	2.72^{c}	2.89^{c}	2.80^{c}	46.43^{bc}	46.32^{cde}	46.37^{bcd}

The means followed by the same letters are not significantly different at $p < 0.05$ level.

RDF: Recommended dose of Fertilizer, CF: Chemical Fertilizer, VC: Vermicompost, OS1: Soligro (*Ascophyllum nodosum*) granular,
OS2: Bioenzyme (liquid), OS3: Opteine (*Ascophyllum nodosum*) filtrate

Figures

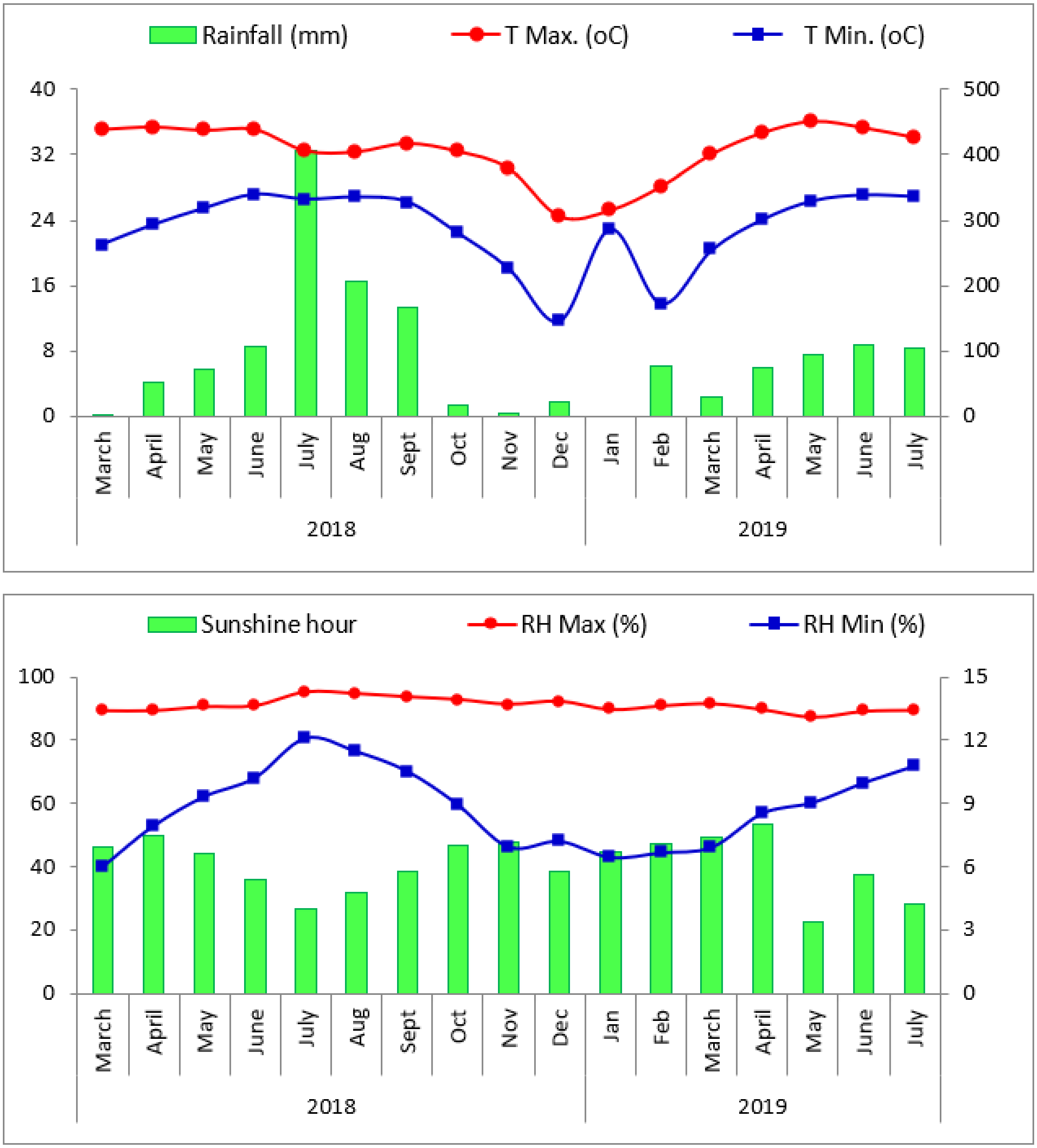
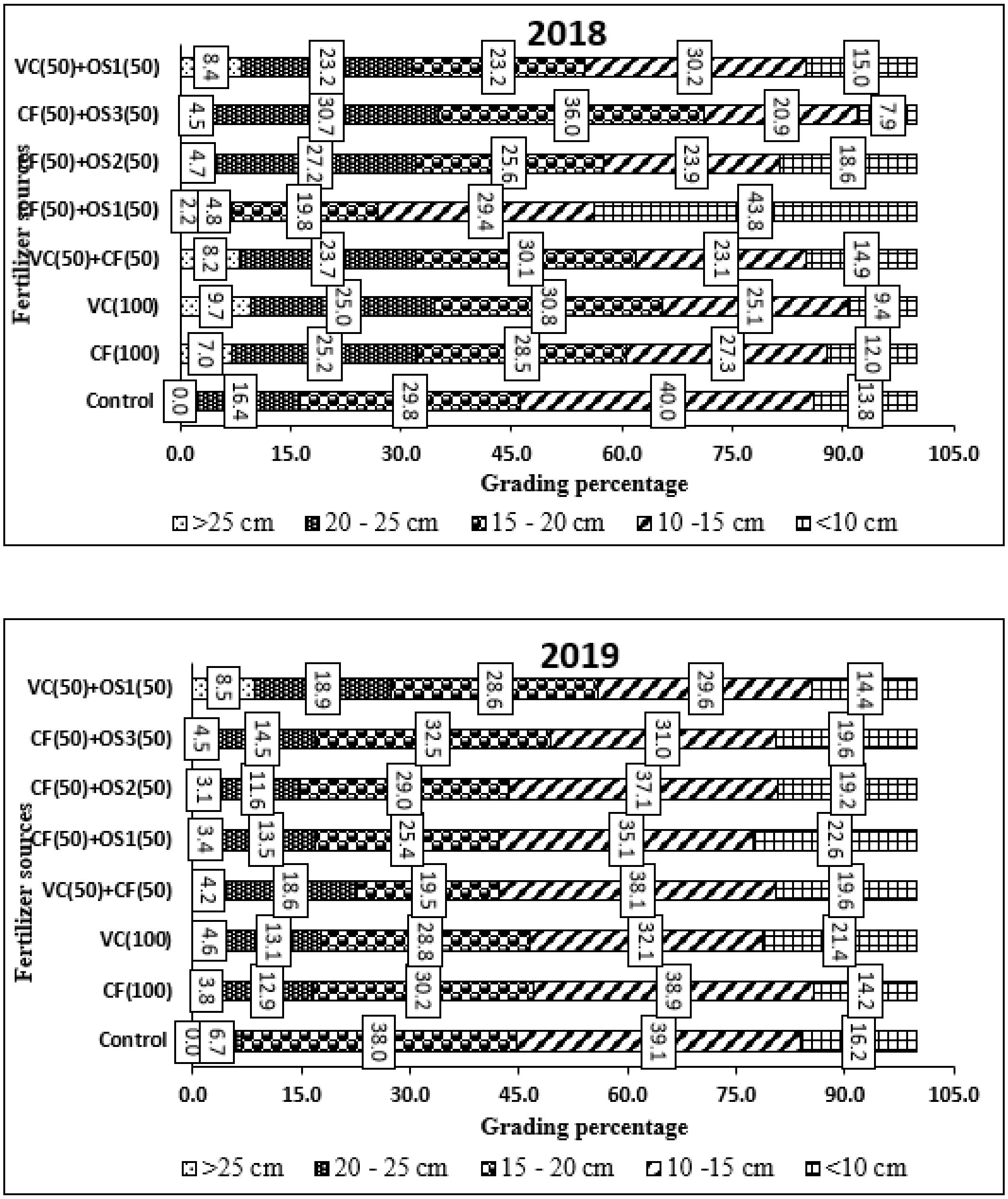


Figure 1

Monthly rainfall and temperature, relative humidity and sunshine hours for different months during the crop growing period of 2018 and 2019



T1: Control, T2: RDF $CF_{100\%}$, T3: RDN $VC_{100\%}$, T4: RDN $CF_{50\%}$ + RDN $VC_{50\%}$, T5: RDN $CF_{50\%}$ + RDN $OS1_{50\%}$, T6: RDN $CF_{50\%}$ + RDN $OS2_{50\%}$, T7: RDN $CF_{50\%}$ + RDN $OS3_{50\%}$, T8: RDN $VC_{50\%}$ + RDN $OS1_{50\%}$

CF: Chemical Fertilizer, VC: Vermicompost, OS1: Soligro granular (*Ascophyllum nodosum*) granular, OS2: Bioenzyme (liquid), OS3: Opteine (*Ascophyllum nodosum*) filtrate

Figure 2

Effect of fertilizer sources on sweet corn cob grading during 2018 and 2019