



Tillage and Seaweed Extract Effects on Soil Physio-chemical Properties, Microbial Population and Yield of Sweet Corn (*Zea mays saccharata* L.) in Hills of Nagaland

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ABSTRACT

Background: Sweet corn is a selectively crossbred variant of maize designed with the intention of enhancing its sugar content. It is highly remunerative and is gaining momentum among the progressive farmers due to its extra sweetness, early maturity, nutritious green fodder at harvest which earns high market value.

Methods: Field experiments were undertaken during *kharif* season of 2021 and 2022 at Experimental Research Farm, Department of Agronomy, SAS, Nagaland University to assess tillage and seaweed extract effects on soil physio-chemical properties, microbial population and yield of sweet corn.

Result: The results from study revealed that yield parameters such as green cob yield, green fodder yield showed significant increase under conventional tillage and application of 10% S-SWE. Highest microbial population was exhibited under zero tilled plots, *Sargassum* seaweed extract (15% S-SWE) application noted significantly higher bacterial, actinomycetes and total microbial population.

Key words: Actinomycetes, Bacteria, Fodder, Microbial, Swe, Sweet corn, Yield.

INTRODUCTION

Wheat, rice and maize are the major cereals in Southeast Asia and Sub-Saharan Africa. Maize is known as the “Queen of cereals” due to its highest genetic yield potential, wider utilization for diverse purposes. *Zea* is an ancient Greek word that means ‘sustaining life’ and *mays* is a word from the Taino language meaning ‘life-giver’ (Milind and Isha, 2013). It is cultivated in many countries due to its wider adaptability to varied agro-climatic conditions and soil types. Currently, nearly 1147.7 million MT of maize is being produced together by over 170 countries from an area of 193.7 million ha with average productivity of 5.75 t ha⁻¹ (Anonymous, 2020a). India ranks 4th in area and 7th in production, representing around 4% of the world maize area and 2% of total production. Together with rice and wheat, maize provides at least 30% of the dietary calories of over 4.5 billion people in 94 countries and by 2050, maize demand in developing countries will double (Das and Karjagi, 2022). In the Indian context, approximately 80% of maize cultivation takes place in regions with rainfed subtropical climates. Sweet corn (*Zea mays* var. *saccharata*) is one among the eight groups of *mays* spp. on the basis of the nature of the endosperm of kernels. The kernels of sweet corn are translucent, having thinner pericarp and more or less wrinkled at maturity. Besides their genetic makeup, sweetness of these varieties is also governed by their management practices and stages of harvest *i.e.* harvest maturity and physiological maturity. In the North East region of India, it has the potential to become a significant crop with its proportion of total area coverage becoming the

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second highest after rice. Corn occupies a place of pride among cereals as it is second important cereal crop grown in Nagaland over an area of 0.69 million ha with 1.4 million tonnes of production, highest among the North eastern states (Statistical Handbook of Nagaland, 2020). However, there is significant yield gap in maize due to lack of adoption of agro-techniques for its cultivation, imbalanced and inappropriate fertilization, poor nutrient supplementation, lack of fertilizer recommendation, cultivation of local low yielding cultivars, poor economic condition of farmers, undulated topography and improper tillage practices (Singh *et al.*, 2015). The productivity level of maize can be increased further by adopting tillage and nutrient management practices which are best suited in climatic conditions and soil types of Nagaland. Nagaland faces significant challenge of soil acidity aggravated by substantial amounts of rainfall. The issues arising from soil acidity, which negatively impact

soil fertility due to the absence of inorganic fertilizers, are the primary factors contributing to its limited productivity (Kumar, 2015). In this situation, seaweed extracts become an alternative to fulfill the burgeoning nutritional demand of maize crop as it is an organic bio-stimulant. Seaweed extracts function as potent biostimulants in a variety of crops such as vegetables, trees, flowering plants and grains. They have been harnessed to effectively showcase their ability to promote sustainable growth and increased yield in different crops, with a notable focus on maize (Mondal *et al.*, 2015; Layek *et al.*, 2015). Hence, the present investigation was conducted to study the influence of tillage along with seaweed extract application on soil physio-chemical properties and yield of sweet corn.

MATERIALS AND METHODS

A fixed plot field study was carried out at the research farm (Agronomy) of School of Agricultural Sciences, Nagaland University, Nagaland, India, situated at 25°45'3.68"N latitude and 93°51'29.79"E longitude at an elevation of 360 m AMSL during 2021-2022. The soil of the experiment site was acidic in reaction (pH 4.86), non-saline (EC 0.06 dS m⁻¹), sandy clay loam in texture, high organic carbon (1.35%), medium available N (210.24 kg ha⁻¹) as well as medium in available phosphorus (23.43 kg ha⁻¹) and available potassium (221.48 kg ha⁻¹). Treatments consisted of 3 tillage practices; conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT) in main plot and sub plot treatment consisted of 2 types of seaweed extract; *Kappaphycus alvarezii* (K-SWE) and *Sargassum wightii* (S-SWE), 3 concentration (5, 10 and 15%) and 3 sprays, scheduled at 30, 50 and 70 days after sowing (DAS) along with control *i.e.* water spray. Seeds were treated with respective concentration and species of seaweed extract spray at respective growth stages prior to sowing in respective treatments. During both the years of experimentation, stock solution @ 500 lit ha⁻¹ was used for foliar spray at mentioned growth stages. Twenty one treatment combinations were tried in a split-plot design and replicated thrice. The gross plot size was 6.0 m×5.0 m and sowing was done at a spacing of 50 cm×20 cm. The recommended dose of nitrogen, phosphorus and potassium, *i.e.* 80:60:40 kg N, P₂O₅ and K₂O kg ha⁻¹ were supplied for sweet corn in the form of urea, single super phosphate and muriate of potash respectively. N was applied in three equal splits as basal, knee height and tasseling stages (30, 50 and 70 DAS). Other intercultural operations were adopted as per recommendations of crop. Data on yield performances were recorded. After harvesting green cobs, the remaining portion of plants were harvested to the base from one meter square area and weighed to get the yield in (kg) from one meter square area. Finally the yield was converted into t ha⁻¹ by multiplying it with conversion factor to get the green fodder yield. The changes in soil physio-chemical properties and microbial population were monitored after completion of experimentation. The soil

samples were analyzed for pH, EC, organic carbon, available N, P and K by standard methods and protocols. Enumeration of bacteria was done on nutrient Agar, Potato dextrose agar (PDA) for fungi and glycerol yeast extract agar for actinomycetes. The count of microorganisms (bacteria, fungi and actinomycetes) was carried out by using serial dilution pour plate method (Wollum, 1982). The data collected were subjected to statistical analysis of variance as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield attributes and yield

Effect of tillage practices

Conventional tillage system exhibited significantly highest yield attributes and yield *viz.* fresh cob weight, green cob yield, green fodder yield and dry fodder yield of sweet corn in both the years (Table 1). It might be due to higher growth and yield attributing parameters caused by better absorption of nutrients from the soil, increased rate of metabolic processes, rate of light absorption and increased rate of photosynthetic activity as compared to minimum and zero tillage. The treatment exhibiting better growth and having superior yield attributes were also observed to be the higher yielders. The effect of conventional tillage on yield parameters in the present study agreed with the findings of Shahid *et al.* (2016). Similar results were also obtained by Ramesh *et al.* (2016) in maize under CT over ZT, however the variation between them in terms of green cob yield was non-significant. The increase in yield could be attributed to the presence of essential nutrients at important growth stages in sufficient quantities, potentially enhancing the sweet corn characteristics, leading to higher green cob and fodder yield. The findings of Rana *et al.* (2013); Kumar and Karmakar (2015) also support the result of present study which revealed that conventional recorded highest green and dry fodder yield of sorghum and oat over zero, minimum and reduced tillage.

Effect of seaweed extracts

Among SWE, spray of *Sargassum* seaweed extract significantly increased the yield attributing characters and yield over control. The significantly higher fresh cob weight, green cob yield, green fodder yield and dry fodder yield were recorded under treatment S-SWE spray 10% over control. SWS contain various marine bioactive substances which improves the yield and quality of crops in positive ways. This increased attributes might be due to spraying of SWE at critical growth stages which was used by the crop in an efficient manner and expressed higher growth and yield (Sivasankari *et al.*, 2006). The present observation on the significant increase in green cob weight is in accordance with Pal *et al.* (2015). Our findings clearly showed that application of S-SWE had significant influence on the green fodder yield of sweet corn, might be due to presence of reasonable quantity of micronutrients and cytokinins in

Sargassum species (Crouch and Staden, 1990). Seaweed extracts exhibit bioactivity even at lower concentrations, typically diluted at ratios of 1:1000 or more (Bokil *et al.*, 1974). The hindered growth at higher concentrations could be attributed to an excess of hormones or an accumulation of minerals. Similar research findings were reported by Zodape *et al.* (2009) in which the increase in yield and yield attributes of wheat crop attributed to the presence of growth-promoting compounds like auxins, cytokinins, gibberellins, micronutrients, vitamins and amino acids. Microelements and plant growth regulators, especially cytokinins, could

contribute to increased green cob yield of sweet corn when receiving seed treatment and foliar applications of respective concentration of at critical growth stages.

Soil physical properties

Data with regard to tillage practices and seaweed extract application failed to bring any significant deviation the in soil physical properties viz. bulk density, particle density and porosity during 2021-2022 (Table 2). However, bulk density slightly increased while particle density slightly decreased in second year in comparison to first year under minimum

Table 1: Tillage and seaweed extract effects on yield parameters of sweet corn.

Treatments	Green cob weight (g cob ⁻¹)		Green cob yield (t ha ⁻¹)		Green fodder yield (t ha ⁻¹)		Dry fodder yield (t ha ⁻¹)	
	2021	2022	2021	2022	2021	2022	2021	2022
Tillage practices (T)								
T1: Conventional tillage	392.40	401.00	18.28	18.70	25.02	26.05	10.33	10.42
T2: Minimum tillage	377.25	387.74	17.24	17.73	23.19	24.84	9.35	9.68
T3: Zero tillage	365.42	378.03	16.44	16.32	21.46	22.6	8.82	8.81
SEm±	3.29	3.50	0.31	0.45	0.67	0.40	0.29	0.26
CD (P=0.05)	11.39	12.12	1.07	1.55	2.30	1.40	1.00	0.89
Seed treatment and seaweed extract spray (S)								
S1: Water spray	361.54	377.26	13.25	13.94	17.74	18.72	7.46	8.09
S2: K- SWE 5%	377.14	386.62	17.62	17.91	22.78	25.07	10.16	10.03
S3: K- SWE 10%	383.26	398.88	18.79	18.77	26.24	27.53	10.44	10.81
S4: K- SWE 15%	373.87	378.03	16.52	16.52	22.15	22.48	8.31	8.53
S5: S- SWE 5%	379.30	389.50	18.51	18.83	24.37	25.84	10.20	10.34
S6: S- SWE 10%	399.21	410.60	19.11	19.63	26.91	28.09	10.76	10.85
S7: S- SWE 15%	374.16	381.59	17.43	17.47	22.38	23.75	9.18	8.79
SEm±	7.06	6.62	0.56	0.60	0.89	1.03	0.40	0.39
CD (P=0.05)	20.42	19.16	1.61	1.72	2.57	2.99	1.17	1.12

K- SWE: *Kappaphycus alvarezii* seaweed extract, S- SWE: *Sargassum wightii* seaweed extract.

Table 2: Tillage and seaweed extract effects on soil physical properties.

Treatments	Bulk density(g cm ⁻³)		Particle density(g cm ⁻³)		Porosity (%)	
	2021	2022	2021	2022	2021	2022
Tillage practices (T)						
T1: Conventional tillage	1.20	1.20	2.70	2.70	54.68	54.60
T2: Minimum tillage	1.21	1.23	2.70	2.68	54.49	53.92
T3: Zero tillage	1.23	1.24	2.67	2.66	53.90	53.33
SEm±	0.01	0.01	0.05	0.04	0.90	0.49
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Seed treatment and seaweed extract spray (S)						
S1: Water spray	1.20	1.22	2.65	2.67	54.23	54.31
S2: K- SWE 5%	1.22	1.21	2.75	2.67	55.40	53.24
S3: K- SWE 10%	1.19	1.22	2.66	2.75	54.05	55.61
S4: K- SWE 15%	1.22	1.21	2.71	2.62	54.96	53.00
S5: S- SWE 5%	1.22	1.23	2.82	2.64	55.95	52.72
S6: S- SWE 10%	1.23	1.22	2.66	2.71	53.05	54.82
S7: S- SWE 15%	1.23	1.24	2.61	2.71	52.86	53.93
SEm±	0.01	0.01	0.06	0.06	1.21	1.06
CD (P=0.05)	NS	NS	NS	NS	NS	NS

and zero tillage. Bulk density (combination of soil and pore space of soil) under zero tillage was subjected to certain amount of compaction which resulted in the less pore space and high bulk density. Porosity under conventional tillage was found to be more than that of minimum and zero tillage from initial porosity value (52.25%) recorded. The relationship of BD and total porosity (TP) was reciprocal. As one increased, the other decreased Abagandura *et al.* (2017). The results were in accordance with the study conducted by Urmila *et al.* (2018) who found that bulk density and particle density didn't show any significant changes in soil due to tillage practices. Corroborating with the present findings Meshram (2021) stated that there was no significant change in bulk density, particle density and porosity of soil after the harvest of maize due to seaweed extract application.

Soil pH, EC and OC (%)

Effect of tillage practices

Soil pH revealed that neither tillage practices nor seaweed extract application led to any significant variations in the pH of soil during the course of investigation (Table 3). Numerically higher value of pH was recorded under conventional tillage as compared to zero tillage. However, after the harvest of sweet corn crop slight decrease in soil pH was noticed in comparison to initial pH in Conventional tillage in comparison to zero tillage. Rasmussen (1999) noted that tillage techniques often had no impact on soil pH, it was reported that no-till systems tended to have lower pH compared to CT. There was slight increase in soil EC under CT in comparison to initial EC. This is in close agreement with the findings of Singh *et al.* (2011). They noticed that conventional system of tillage slightly increased salts concentration from 0.01 to 0.02 dS m⁻¹ while conservation methods maintained somewhat near to the original level. Variations on soil organic carbon due to tillage

practices were found to be non-significant. Yet, soil OC post-harvest of sweet corn slightly increased from its initial under ZT and recorded numerically higher value of SOC. This might be due to the less oxidative losses of SOM. When soil is deeply tilled, more of oxygen reaches the inner layers enhancing the oxidative processes.

Effect of seaweed extracts

Among seaweed treatments, no clear cut trend in soil pH was noticed after harvest of sweet corn during first and second year, irrespective of the species and concentration of seaweed extract applied. However, seaweed extract application induced slight changes in soil EC after harvest of sweet corn. Organic carbon of soil also remain unaffected but application of S-SWE 10% recorded numerically more OC. Similar observations were made by Layek *et al.* (2019) who reported that soil organic carbon was not significantly influenced by seaweed extract concentration.

Soil-nutrient status after harvest

Results of the study conducted depicted in (Table 4) unveiled that tillage practices and seaweed extract application did not cause any significant changes in available nitrogen, phosphorus and potassium of soil. Though, it was noticed that rate of enhancement of available nitrogen in soil at harvest was more with zero tillage in comparison with conventional tillage in the second year which may be attributed due to retention of previous crop residues and less leaching losses under zero tillage (Gupta *et al.*, 2011). Contrarily, conventional tillage recorded numerically higher content of available phosphorus and potassium. Among seaweed extract treatment there was a lack of consistent patterns observed in terms of soil available nutrients after the harvest of sweet corn. These findings are in affirmation with the study conducted by Layek *et al.* (2019) who found

Table 3: Tillage and seaweed extract effects on soil pH, EC and OC.

Treatments	Soil pH		Soil EC (dSm ⁻¹)		SOC (%)	
	2021	2022	2021	2022	2021	2022
Tillage practices (T)						
T1: Conventional tillage	4.72	4.67	0.08	0.09	1.35	1.35
T2: Minimum tillage	4.59	4.66	0.07	0.07	1.35	1.36
T3: Zero tillage	4.47	4.56	0.05	0.06	1.37	1.39
SE _{mt}	0.07	0.1	0.01	0.01	0.01	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Seed treatment and seaweed extract spray (S)						
S1: Water spray	4.62	4.59	0.07	0.10	1.33	1.34
S2: K- SWE 5%	4.51	4.47	0.07	0.08	1.35	1.37
S3: K- SWE 10%	4.8	4.74	0.06	0.06	1.36	1.39
S4: K- SWE 15%	4.61	4.68	0.07	0.06	1.36	1.37
S5: S- SWE 5%	4.52	4.63	0.06	0.08	1.37	1.37
S6: S- SWE 10%	4.57	4.55	0.06	0.08	1.35	1.36
S7: S- SWE 15%	4.54	4.76	0.06	0.07	1.38	1.39
SE _{mt}	0.11	0.13	0.01	0.01	0.03	0.03
CD (P=0.05)	NS	NS	NS	NS	NS	NS

that soil available N, P and K didn't significantly change while higher seaweed extract concentrations showed a slight reduction.

Microbial (bacteria, fungi and actinomycetes) population in soil after harvesting

Effect of tillage practices

Zero tillage practices resulted in significantly higher bacterial, fungal and actinomycetes population during first and second year of study, whereas, conventional tillage resulted in significantly lower population of microorganisms after harvest of the crop (Table 5). In no-till soils, the accumulation of crop residues on the soil surface results in enrichment of

soil organic matter in the surface layer and as a consequence increased abundance of microorganisms (Mathew *et al.*, 2012) while Chowdhury *et al.* (2008) mentioned that at the harvest stage of rice, different tillage systems were found to be statistically similar with respect to fungal, bacterial and actinomycetes population. The above result coincides with the observations of Dongre *et al.* (2017).

Effect of seaweed extract

Microbial population after harvest of sweet corn showed an increasing trend with increase in concentration of seaweed extract spray. However, S-SWE performed better than K-SWE in improving the population and the maximum microbial

Table 4: Tillage and seaweed extract effects on available nitrogen, phosphorus and potassium.

Treatments	Available N (kg ha ⁻¹)		Available P (kg ha ⁻¹)		Available K (kg ha ⁻¹)	
	2021	2022	2021	2022	2021	2022
Tillage practices (T)						
T1: Conventional tillage	253.07	255.28	26.87	28.19	236.88	238.93
T2: Minimum tillage	249.79	253.93	25.52	27.86	236.19	238.92
T3: Zero tillage	245.94	250.52	23.06	26.11	230.36	236.02
SEm±	3.84	3.74	1.12	1.03	4.64	3.61
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Seed treatment and seaweed extract spray (S)						
S1: Water spray	242.77	247.56	26.19	29.69	222.46	239.04
S2: K- SWE 5%	247.91	250.41	23.23	26.26	247.12	228.8
S3: K- SWE 10%	252.52	252.07	25.27	27.34	227.38	240.68
S4: K- SWE 15%	243.34	263.53	26.20	27.85	228.06	241.39
S5: S- SWE 5%	253.99	258.33	24.09	27.74	233.78	242.74
S6: S- SWE 10%	251.39	252.35	25.86	28.45	235.84	230.99
S7: S- SWE 15%	255.28	248.44	25.20	24.39	246.69	242.03
SEm±	4.21	6.30	1.57	1.34	8.85	5.26
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 5: Tillage and seaweed extract effects on soil microbial population (CFU g⁻¹ of soil).

Treatments	Bacteria (×10 ⁵) g ⁻¹ soil		Fungi (×10 ⁵) g ⁻¹ soil		Actinomycetes (×10 ⁵) g ⁻¹ soil	
	2021	2022	2021	2022	2021	2022
Tillage practices (T)						
T1: Conventional tillage	36.67	38.14	13.76	15.19	57.71	59.14
T2: Minimum tillage	39.43	41.76	15.24	17.24	60.10	62.05
T3: Zero tillage	42.50	45.48	17.52	20.48	64.00	68.1
SEm±	0.96	0.84	0.51	0.47	1.05	0.32
CD (P=0.05)	3.33	2.89	1.77	1.63	3.63	1.10
Seed treatment and seaweed extract spray (S)						
S1: Water spray	33.89	35.78	12.44	13.00	56.11	56.67
S2: K- SWE 5%	39.44	39.78	15.00	16.11	63.22	63.89
S3: K- SWE 10%	41.70	42.00	14.89	20.67	58.22	62.89
S4: K- SWE 15%	40.78	43.11	16.78	17.78	60.56	65.44
S5: S- SWE 5%	39.89	41.56	15.78	18.00	61.67	62.56
S6: S- SWE 10%	39.56	45.00	17.22	18.67	62.00	65.11
S7: S- SWE 15%	41.48	45.33	16.44	19.22	62.44	65.11
SEm±	1.56	1.46	1.00	0.89	1.64	1.49
CD (P=0.05)	4.52	4.23	2.90	2.56	4.76	4.32

population (bacteria and actinomycetes) was noted with the application of S-SWE 15%. The addition of organic fertilizers aids in decomposition and enhances microbial activity. These results confirm the findings of the Mohanty *et al.* (2013) who mentioned that brown seaweeds, rich in polysaccharides and hydrophilic properties, have agricultural and pharmaceutical significance. Alginate in seaweed cell walls forms high molecular weight complexes with soil ions, improving soil moisture retention, aeration and capillary activity. This benefits plant root system growth and microbial activity (Gandhiyappan and Perumal, 2001).

CONCLUSION

The yield components and soil microbial population after harvest of sweet corn were significantly influenced by tillage practices and seaweed extract foliar application. The highest yield was obtained with conventional tillage and application of 10% S-SWE, whereas, zero tillage practices resulted in increased microbial population and soil organic carbon with time. So, practicing zero tillage might be suggested for better performance of a crop and soil health in long term.

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Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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