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Growth Allometry of Sweet Corn as Influenced by Tillage and Seaweed under Tarai Region of Nagaland

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Abstract

A study was carried out at Crop Research Farm, Department of Agronomy, SAS, Nagaland University, Nagaland, India during *kharif* (May-September, 2021 and 2022) situated at 25° 45′ 3.68″N latitude and 93° 51′ 29.79″ E longitude, to study the influence of tillage and seaweed extract on growth allometry of sweet corn under tarai region of Nagaland. The experiment was conducted in split plot design with two factor treatment and was replicated thrice. Factor one comprised of three tillage practices viz., conventional tillage, minimum tillage and zero tillage in the main plots and factor two included seven treatments consisting of seed priming followed by foliar spray of seaweeds i.e. *Kappaphycus alvarezii* and *Sargassum wightii* viz., water spray (control), K-Seaweed sap 5%, K-Seaweed sap 10%, K-Seaweed sap 15%, S-Seaweed sap 5%, S-Seaweed sap 10%, S-Seaweed sap 15%, in the sub-plots at 30, 50 and 70 days after sowing. Results of study revealed that significantly higher stem girth, leaf area, leaf area index, leaf area duration, SPAD meter reading at different intervals were noticed in conventional tillage. When seeds were treated with 10% S-Sap along with 10% S-Sap spray at three different intervals recorded significantly higher stem girth, number of functional leaves plant^{-1}, leaf area, leaf area index, leaf area duration and chlorophyll index readings.

Keywords: Conventional, minimum, *Kappaphycus, Sargassum*, SPAD, sweet corn

1. Introduction

Maize stands out as a highly adaptable and versatile crop, thriving in diverse agro-climatic conditions. Its physiological efficiency, attributed to the C_4 pathway, grants it the highest genetic yield potential among food grain crops (Bhat et al., 2022). With its year-round cultivation capability and insensitivity to photoperiod, maize earns the title of the "queen of cereals" globally due to its exceptional genetic yield potential (Sethi et al., 2021). Sweet corn is hybridize version of maize specifically breed to increase its sugar content. It is a genetic variant of corn that accumulates more sugar and less starch in the ear (Murdia et al., 2016). Its popularity is on the rise both domestically and internationally owing to the delectable sweetness and tenderness of its kernels, making it increasingly cultivated nationwide and ensuring favorable returns for farmers. The distinct flavor, texture and sweetness of sweet corn kernels can be attributed to certain endosperm mutants that influence the starch biosynthesis pathway in the endosperm (Chouhan et al., 2022). At the milky stage, sweet corn typically contains a total sugar content ranging from 25–30%, significantly higher compared to the 2–5% found in normal corn. Maize occupies a place of pride among cereals as it is second important cereal crop grown in Nagaland over an area of 0.69 mha with 1.4 mt 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, undulated topography and improper tillage practices etc (Singh et al., 2015). Minimal external inputs exacerbate these stresses, particularly in acid soils, further limiting productivity (Kumar, 2015, Murdia et al., 2016). The average productivity of maize in the region is very low (<1.5 t ha^{-1}) (Ansari 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. Tillage is the basic and one of the most important components of crop production system which provides favorable condition for plant growth and influences crop yield to a greater extent. A compact and firm seedbed significantly hampers the growth of seedlings and has a substantial impact on crop yield. The outcome of the crop production process, which is affected by multiple elements, relies heavily on the conditions of the seedbed (Fanigliulo et al., 2021). There is a need for adoption of the different tillage practices in India for harnessing maximum crop production profitability (Yadavet al., 2016). Farmers have apathy towards use of agrochemicals in crop production in north eastern region of India (Das et al., 2018). In this situation, seaweed extracts become an alternative to fulfill the nutritional demand of maize crop as it is an organic bio-stimulant. These extracts, derived from seaweeds, hold significance as sources of biostimulants. 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; Layeket al., 2015; Meshram; 2021). Seaweed is rich in macro and micronutrients, growth promoting hormones like IAA, IBA, cytokinins and gibberellins. Many researchers proved that the foliar application of*Kappaphycus alvarezii* (Zodape et al., 2011) and *Sargassum* sp. (Fatriana et al., 2020) advanced productiveness and great of crop without impairing the soil fertility. Numerous research investigations have shown that the utilization of seaweed extracts, in combination with chemical fertilizers or organic fertilizers, effectively boosts crop productivity. So, keeping the above facts in view, a study was undertaken to investigate the effect of tillage practices combined with seaweed sap application on the physiological indices of sweet cornunder Tarai region of Nagaland.

2. Materials and Methods

A field study was conducted at Crop Research Farm, Department of Agronomy, SAS, Nagaland University for a period of two years during *kharif* (May-September, 2021 and 2022). The farm is situated between 25° 45′ 3.68″N latitude and 93° 51′ 29.79″ E longitude and at an elevation of 360 meters above mean sea level. The experimental farm is located within a humid sub-tropical area characterized by an average annual rainfall ranging from 2000 to 2500 mm. The temperatures typically range from 28 to 32°C in the summer and seldom drop below 8°C during the winter months due toelevated atmospheric humidity. The climate in the region follows a wet-dry pattern with distinct monsoon seasons. The soil of experimental area was sandy clay loam, acidic in reaction, high in organic carbon and medium in available nitrogen, phosphorus and potassium. The experiment comprised of twenty one treatment combinations consisting three tillage practices viz., conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT), with two species of seaweeds i.e. *Kappaphycus alvarezii* (K-Sap) and *Sargassum wightii* (S-Sap) sprayed at three different concentration (5, 10 and 15%) at 30, 50 and 70 DAS with control (water spray). Seeds were soaked separately in seaweeds with different concentrations i.e. 5, 10 and 15% as per treatments prior to sowing. A rectangular experimental area having uniform topography was selected for conducting the experiment. Main plots were prepared according to factor one treatments. The gross plot size was 6.0×5.0 m^2 and sowing was done at a spacing of 50×20 cm^2. The recommended dose of nitrogen, phosphorus and potassium, i.e. 80:60:40 kg N, P_2O_5 and K_2O 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. Other agronomical operations were carried out as per recommendation. The observations onstem girth, number of leaves, leaf area, leaf area index, leaf area duration and SPAD readings were taken at an interval of 15 days. The stem girth of five tagged plants was measured near the base, middle and top with vernier caliper and then average was calculated and expressed in centimeter. The leaves from each plant selected and cut just above the ground level with the help of sickle at 15, 30, 45, 60 DAS and at harvest. All the leaves from five selected plants were removed and categorized in to three groups viz., large, medium and small. Three representative leaves from each category were taken out to measure length and width. The average values of leaf length and width was multiplied to get leaf area of each respective category. Leaf area recorded from each category was multiplied by the total number of leaves of respective category and summed up to get the total leaf area of sample. Average leaf area $plant^{-1}$ was computed by dividing the value obtained by five. The whole value was multiplied by correction factor of 0.75 (Montgomery, 1911). The formula of average leaf area $plant^{-1}$ used was,

Average leaf area $plant^{-1}$ (cm^2) =(No.of small leaves × (L × W of small leaves)+@No.of medium leaves×(L×W of medium leaves)+@"No.of large leaves×(L×W of large leaves)@@/ Number of sampled plants)×0.75

Where,

L and W are the average length and width of leaves in cm, respectively.

Leaf area duration was calculated by formula,

$LAD (days)=LAI_1+LAI_2)/2×(t_2-t_1)$

Where,

LAD=Leaf area duration between t_2 and t_1

LAI_1=LAI at time t_1

LAI_2=LAI at time t_2

SPAD values (Chlorophyll content) was observed from the 4 uppermost fully expanded leaf on each plant at an interval of 15 days, 3 SPAD values per leaf, including one value around the midpoint of leaf blade and 2 values at 3 cm apart from midpoint were averaged as the mean SPAD value of the leaf (Peng et al., 1993). All the data collected were subjected to statistical analysis of variance as described by Gomez and Gomez (1984).

3. Results and Discussion

3.1. *Stem girth (cm)*

Pooled data of two years of study revealed that there was no significant effect of tillage practices on the stem girth at initial stages of crop growth i.e. 15 and 30 DAS (Table 1). However, conventional tillage produced significantly more stem girth at 45, 60 DAS and at harvest succeeded by minimum and zero tillage. Zero tillage recorded the least improvement among all. The findings of Aikins et al. (2012) supported the result of present study who noted that disc harrowing treatment resulted in highest stem girth.

Seed treatment followed by seaweed sap spray significantly influenced the stem girth irrespective of species and concentration of sap used except at early stage (15 DAS). Significant difference was noticed due to seed priming with 10% S-Sap followed by foliar spray of S-Seaweed sap at 10% concentration which produced maximum stem girth at 30 DAS, 45 DAS, 60 DAS and at harvest which were significantly superior to the rest except foliar application of K-Seaweed sap at 10% and S-Seaweed sap 5% at 30, 45 and 60 DAS which were at par. Water spray (i.e.control) recorded significantly the least stem girth. Sweet corn's metabolism was stimulated by the foliar application of SWS at critical growth stages, which helped the crop to develop into a robust and healthy plant (Pal et al., 2015 and Basavaraja et al., 2018). Applying SWS containing micronutrients (such as Co, B, Mo, Zn, Cu) and macronutrients, along with growth hormones (auxin, cytokinin and gibberellin) can increase plant stalk thickness and root capacity for the absorption of nutrients, strengthening vegetative growth and plant roots leading to improved stalk quality and reduced vulnerability to collapse. This suggests that *Sargassum sp*. algae can boost growth during the vegetative phase.

3.2. *Number of functional leaves plant^{-1}*

The number of functional leaves plant^{-1}did not varied significantly among tillage practices at different growth stages. However, numerically more number of leaves plant^{-1}was noticed under conventional tillage at all growth stages of sweet corn (Table 1).

Application of seaweed sap failed to elicit any significant influence on number of green leaves of sweet corn at 15 and 30 DAS. Although the number of leaves plant^{-1} increased with increasing K and S-Sap concentration up to 10%, thereafter it gradually declined. Pooled data exhibited that maximum

Table 1: Stem girth and number of functional leaves plant-1of sweet corn as influenced by tillage and seaweed-sap

Treatments	Stem girth (cm)					No. of leaves plant^{-1}				
	15 DAS	30 DAS	45 DAS	60 DAS	At harvest	15 DAS	30 DAS	45 DAS	60 DAS	At harvest
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Tillage practices (T)										
T_1: Conventional tillage	0.35	0.80	1.47	2.20	2.26	3.86	7.87	10.58	11.84	10.55
T_2: Minimum tillage	0.33	0.78	1.45	2.04	2.10	3.69	7.77	10.26	11.61	10.40
T_3: Zero tillage	0.32	0.76	1.40	1.80	1.95	3.62	7.60	10.19	11.27	10.23
SEm±	0.01	0.01	0.01	0.04	0.03	0.10	0.15	0.17	0.23	0.12
CD (*p*=0.05)	NS	NS	0.03	0.14	0.10	NS	NS	NS	NS	NS
Seed treatment and seaweed-sap spray (S)										
S_1: Water spray	0.31	0.73	1.29	1.73	1.87	3.53	7.4	9.62	10.75	9.6
S_2: K- Seaweed sap 5%	0.34	0.78	1.48	1.91	2.07	3.67	7.78	10.16	11.39	10.41
S_3: K- Seaweed sap 10%	0.35	0.82	1.50	2.16	2.27	3.88	7.88	10.95	12.01	10.75
S_4: K- Seaweed sap 15%	0.32	0.73	1.39	1.99	1.97	3.6	7.48	9.82	10.97	10.17
S_5: S- Seaweed sap 5%	0.34	0.80	1.48	2.12	2.12	3.76	7.83	10.49	11.76	10.52
S_6: S- Seaweed sap 10%	0.35	0.84	1.51	2.26	2.38	4.02	8.09	11.35	12.94	11.00
S_7: S- Seaweed sap 15%	0.33	0.76	1.42	1.90	2.04	3.62	7.76	10.01	11.18	10.3
SEm±	0.01	0.02	0.02	0.06	0.03	0.14	0.17	0.21	0.24	0.21
CD (*p*=0.05)	NS	0.05	0.05	0.18	0.10	NS	NS	0.6	0.7	0.6

number of leaves plant^{-1} at 45 DAS, 60 DAS and at harvest were recorded with foliar application of S-Seaweed sap at 10%. The minimum number of functional leaves plant^{-1} at harvest was produced under control (water spray). The presence of growth-promoting substances in seaweed plays a crucial role in enhancing cell size and division. Zeatin, a natural cytokinin andvarious cytokinins found in abundance in brown algal extracts have important roles in plant growth and development, including cell division, shoots initiation, proliferation, chloroplast development, and senescence regulation (Mok and Mok, 2001). This confirms the findings of Pal et al. (2015) who noted more number of functional leaves with seaweed sap application over control. Similar results were obtained by Layek et al. (2019).

3.3. Leaf area plant^{-1}(cm^2)

Leaf area is the index of photosynthetic efficiency. The results presented in (Table 2) portrayed that tillage practices recorded significant difference in the leaf area at all periodic growth stages except at initial (15 DAS). CT was found to perform significantly superior than MT and ZT at 30 DAS, 45 DAS, 60 DAS and at harvest while minimum leaf area was noticed under ZT at all periodic intervals. These observations confirms the work of Gul et al. (2009) who noted lower values of leaf area plant^{-1} in ZT as compared to CT.

Application of seaweeds had no significant influence on leaf area of sweet corn at 15 DAS. However, remarkable variations in leaf area were recorded further due to foliar application ofseaweed sap. Data exhibited that foliar spray of S-Seaweed sap 10% recorded significantly highest leaf area and was found to be statistically superior over the other species andconcentration of sap spray. However, it was found to be at par with K-Seaweed sap 10% foliar spray. The increase in growth variables observed in plants treated with seaweed extract might be due to enhanced magnesium, phosphorus, potassium, nitrate and iron uptake. The physiological responses resulting from seaweed extract spraying include improved nutrient mobilization, root system development, increased chlorophyll content, andexpanded leaf area. In tomato plants, foliar application of seaweed (*Sargassum crassifolium*) with lower concentrations has been found to boost growth by increasing photosynthesis through the expansion of leaf area. The longer the leaf area is sustained during the growing season, the more energy and nutrients the crop can produce, resulting to higher yield. The findings are in accordance with those Singh et al. (2016) and Pramanick et al. (2018) who reported increased in leaf area with SWS application.

3.4. Leaf area index (LAI)

Leaf area index is the ratio of leaf area (assimilatory source) per plant by land area. Leaf area index increased as the growth of sweet corn progressed and the values were found to be maximum at peak growth stage i.e. at 60 DAS (Table 2). The LAI

Table 2: Leaf area (LA) and leaf area index (LAI) of sweet corn as influenced by tillage and seaweed-sap

Treatments	Leaf area (cm^2)					Leaf area index				
	15 DAS	30 DAS	45 DAS	60 DAS	At harvest	15 DAS	30 DAS	45 DAS	60 DAS	At harvest
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Tillage practices (T)										
T_1: Conventional tillage	281.75	852.14	2216.19	3243.81	2874.29	0.28	0.85	2.22	3.24	2.87
T_2: Minimum tillage	300.21	811.75	2059.05	3095.00	2645.00	0.30	0.81	2.06	3.10	2.65
T_3: Zero tillage	283.17	776.35	1941.90	2975.48	2493.81	0.28	0.78	1.94	2.98	2.49
SEm±	7.73	4.80	31.45	24.26	32.27	0.01	0.00	0.03	0.02	0.03
CD (p=0.05)	NS	16.62	108.83	83.96	111.69	NS	0.02	0.11	0.08	0.11
Seed treatment and seaweed-sap spray (S)										
S_1: Water spray	266.48	563.33	1867.78	2896.67	2048.89	0.27	0.56	1.87	2.90	2.05
S_2: K- Seaweed sap 5%	283.33	838.33	2058.33	3104.44	2730.56	0.28	0.84	2.06	3.10	2.73
S_3: K- Seaweed sap 10%	299.39	895.00	2223.89	3245.00	2931.11	0.30	0.90	2.22	3.25	2.93
S_4: K- Seaweed sap 15%	282.41	795.19	1953.33	2936.67	2459.44	0.28	0.80	1.95	2.94	2.46
S_5: S- Seaweed sap 5%	298.89	860.36	2091.67	3170.56	2887.78	0.30	0.86	2.09	3.17	2.89
S_6: S- Seaweed sap 10%	290.56	922.22	2325.00	3386.67	3054.44	0.29	0.92	2.33	3.39	3.05
S_7: S- Seaweed sap 15%	297.59	819.44	1986.67	2993.33	2585	0.30	0.82	1.99	2.99	2.59
SEm±	7.88	11.57	46.26	58.57	59.09	0.01	0.01	0.05	0.06	0.06
CD (p=0.05)	NS	33.47	133.86	169.47	170.99	NS	0.03	0.13	0.17	0.17

value was found to be significantly higher in CT as compared to MT and ZT at all crop stages except at 15 DAS and significantly lowest LAI was recorded in ZT. The crop might have performed better overall if there had been more LAI because it may have improved photosynthesis and assimilation rates, which in turn increased dry matter and improved growth indices. The findings of Aikins et al. (2012) and Abagandura et al. (2017) also support the result of present investigation who elucidated that zero tilled plots recorded lesser value of leaf area index as compared to conventional tillage.

Foliar application of seaweed sap had non-significant effect on LAI at initial stage; however, significant difference in LAI was apparent afterwards. Maximum value of LAI at 30, 45, 60 DAS and at harvest was observed with S-Seaweed sap foliar spray 10% which was found to be at par with the foliar application of K-Seaweed sap spray 10%. Maximum LAI was observed at 60 DAS and thereafter it reduced while minimum LAI value was recorded under control. Seaweed extracts regulated plant bio-physiological activities, resulting in the maintenance of increased photosynthetic activities (Singh and Chandel, 2005). Thereness of high marine bioactive materials in SWS enhances stomatal intake ability in S-Sap treated plants. A gradual increase in LAI was noticed with increasing sap concentration up to 10% irrespective of the species of sap applied (Pramanick et al., 2013).

3.5. Leaf area duration (LAD)

The pooled data indicated that tillage practices failed to show any significant variations in LAD at 0–15 DAS (Table 3) whereas, it was found to be significantly higher at different growth stages under conventional tillage followed by minimum and zero tillage.

Seed treatment and application of seaweed sap had notable effect on the LAD of sweet corn at all the growth stages except 0–15 DAS. Seed treatment followed by foliar application of S-Seaweed sap at 10% concentration resulted in maximum LAD. It was observed that LAD gradually increased with increasing sap concentration up to 10%, afterwards it gradually reduced. This was closely followed by application of 10% of K-Seaweed sap. However, minimum value of LAD was obtained with water spray. Leaf area duration is a critical concept in the growth, development and overall quality of the crop. It expresses the continued existence of assimilatory surface area throughout time, which is needed for prolonged photosynthetic activity and ultimate crop productivity. SWS are a rich source of P, K and Mg, micronutrients like Cu, Zn, Fe and Mn as well as other beneficial elements like Ni and Na among others. Furthermore, the presence of magnesium and cytokinin, which are key components of plant synthesis of chlorophyll, in the seaweed extract may have had an essential function in improving the physiology and growth of the crop (Sivasankari et al., 2006).

Table 3: Leaf area duration (LAD) and chlorophyll index (SPAD) of sweet corn as influenced by tillage and seaweed-sap

Treatments	Leaf area duration (days)					Chlorophyll index (SPAD)			
	0-15 DAS	15-30 DAS	30-45 DAS	45-60 DAS	60 DAS - Harvest	15 DAS	30 DAS	45 DAS	60 DAS
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Tillage practices (T)									
T_1: Conventional tillage	2.11	8.50	22.64	40.12	45.43	34.95	37.90	38.67	39.95
T_2: Minimum tillage	2.25	8.34	21.27	37.90	42.56	34.41	37.23	37.81	38.67
T_3: Zero tillage	2.12	7.95	20.07	35.91	40.36	34.10	35.93	36.71	37.63
SEm±	0.06	0.04	0.19	0.20	0.41	0.54	0.22	0.30	0.21
CD (p=0.05)	NS	0.14	0.66	0.68	1.42	NS	0.75	1.03	0.72
Seed treatment and seaweed-sap spray (S)									
S_1: Water spray	2.00	6.22	15.78	29.41	33.23	33.81	35.10	35.30	36.25
S_2: K- Seaweed sap 5%	2.13	8.41	21.73	38.80	43.85	34.54	37.17	37.87	38.84
S_3: K- Seaweed sap 10%	2.25	8.96	23.52	41.51	46.69	34.81	37.65	39.33	40.55
S_4: K- Seaweed sap 15%	2.12	8.08	20.61	36.06	39.86	34.02	36.59	36.49	37.57
S_5: S- Seaweed sap 5%	2.24	8.69	22.14	39.76	45.73	34.75	37.38	38.05	39.15
S_6: S- Seaweed sap 10%	2.18	9.10	24.48	43.25	48.59	35.29	38.57	39.86	40.99
S_7: S- Seaweed sap 15%	2.23	8.38	21.05	37.05	41.53	34.20	36.67	37.24	37.91
SEm±	0.06	0.11	0.31	0.58	0.82	0.55	0.38	0.41	0.44
CD (p=0.05)	NS	0.31	0.90	1.68	2.37	NS	1.11	1.19	1.28

3.6. Chlorophyll index (SPAD)

Chlorophyll index was significantly influenced by tillage practices after 15 days of sowing (Table 3). CT gave maximum leaf SPAD value at 30 DAS, 45 DAS and at 60 DAS followed by MT and ZT. SPAD value gives an indirect measurement of the nitrogen content of maize leaf. Irrespective of treatment, SPAD value increased up to silking and gradually declined towards the senescence. Increase in SPAD values under CT might be due to increase in chlorophyll content viz., correlated with an increase in the net photosynthetic rate.

There were significant variations among the treatments at all growth stages recorded except at 15 DAS with seaweed sap application. Increasing sap concentration up to 10% of both the species of Seaweed displayed the higher SPAD value and further increasing the concentration up to 15%, gradually reduced the values. Sweet corn sprayed with 10% S-Seaweed sap exhibited significant variations with maximum SPAD at 30, 45 and at 60 DAS. In comparison to other the methods of applying nutrients to the soil, foliar application of mineral nutrients enables plants to get nutrients more rapidly (Shah et al., 2013). The increase in chlorophyll content is a result of reduced chlorophyll degradation, likely influenced by existence of amino acids, betaines and other active substances in the seaweed extract (Whapham et al., 1993, Sivasankari et al., 2006).

3.7. Interaction effect

Combined effect of tillage and seaweed sap did not reach the level of significance for stem girth, number of function leaves plant^{-1}, leaf area, leaf area index, leaf area duration and SPAD (chlorophyll index).

4. Conclusion

Sweet corn variety 'Misthi' performed remarkable in terms of growth parameters i.e. stem girth, leaf area, leaf area index, leaf area duration and SPAD meter reading which was significantly higher under conventional tillage with the application of S-Seaweed sap 10% through seed priming followed by foliar spray over other treatments in sandy clay loam soil of Tarai region of Nagaland. This treatment was followed by CT+application of K-Seaweed sap 10%. Overall, the seaweed sap application improved the growth attributes over control (water spray).

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