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ORIGINAL PAPER

The Impact of Using Microalgae as Biofertilizer in Maize (*Zea mays* L.)

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Abstract Fertilizers play a key role in yield if agriculture crops and their market value. Hence, large scale production of low cost, eco-friendly and broad spectrum fertilizers are mandatory. This study was to assess the effect of marine microalgal fertilizer on growth and yield of maize (*Zea mays* L.). The maize plants were raised in soil supplemented with two marine microalgae (*Chlorella vulgaris* and *Spirulina platensis)* along with cow dung manure for 75 days under green house condition. The marine microalgal treatment increased growth performance at the early stage of growth and improved yield characteristics, in addition to increased seed germination. Cow dung and two marine microalgae mixture treatment exhibited high growth and yield revealed the potential of the marine microalgae as fertilizer in cultivation of maize.

Keywords Agriculture · Bio-fertilizer · Cow dung · *Spirulina platensis* · *Chlorella vulgaris* · Maize

Introduction

Microalgae are agriculturally significant source of biofertilizers, predominantly for the tropical rice fields. Cyanobacterial biofertilizers served for a variety of purposes including soil enrichment in fixing atmospheric nitrogen and essential microelements for the growth of crop plants such as rice and wheat. Additionally, algae produce bio-active compounds (secondary metabolites) that inhibit the growth of plant pathogenic bacteria [11, 24] and fungi [11, 24, 42] and increase growth and development of some plant species. The microalgae also provide organic matter for plant growth [17, 28, 39, 45, 49, 50]. The usage of cow dung in gardens is a widely accepted practice in several rural areas. Cow dung is rich in organic materials and nutrients. It is comprised of about 3% N, 2% P and 1% K [28]. Composted cow manure is beneficial to the plant growth.

Maize the most significant cereal crop, globally cultivated for food, feed and other industrial purposes. It is the source of vital nutrition to human and animals. It is also used as a raw material for industrial products including malto dextrins, corn starch, corn syrup, corn oil and fermented products. The global consumption of maize as food was estimated to be 21% of the total production. It holds the third most vital food grain in India subsequent to wheat and rice. Among which, 28, 11, 48, 12 and 1% of maize is used for consumption, livestock feed, poultry feed, wet milling industry and seed respectively [4]. In the past years, there was a dramatic increase in the production and productivity of maize in India, mainly due to adoption of single cross hybrids. Consequently, its production registered an annual growth rate of 6.4% (2007–2010), the highest among food crops and surpassing 4% growth rate for agriculture in general and 4.7% for maize in particular as the target set by the Planning Commission, Government of India. In the country, more than three-fourths of the area to maize production is contributed by eight states, viz Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh and Tamil Nadu. Since the demand for maize is increasing consistently, it deserves much attention for improvement of its growth and yield. Bearing this in mind, the present study was made to study the effect of microalgae *(Spirulina platensis* and *Chlorella vulgaris)* along with cow dung manure

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on growth performance, soil characteristics, macronutrients and micronutrients and its microbial population at flowering stage of maize. Further the yield characteristics of maize, biochemical composition of corn cobs and its mineral contents. In addition further efforts were taken to analyze the physical characters and germinability characters in seeds produced by maize under microalgal treatments (Fig. 1).

Materials and Methods

Algal Culture

The marine algal strains of *C. vulgaris* and *S. platensis* maintained in Microalgal laboratory of CAS in Marine Biology, Faculty of Marine Sciences, Annamalai University, Tamil Nadu, India were used for this study. BG11 medium [66] was used for the growth of *C. vulgaris* and Zarrouk medium [69] for *S. platensis*. Both cultures were incubated under continuous illumination (4500 lx by maintaining the temperature of 25 °C ± 2 °C for *C. vulgaris* and 35 °C ± 2 °C for *S. platensis* and pH range of 9–10).

Maize Experimental Cultivation

The experiment was conducted for 75 days and the experimental design was showed in Fig. 1. The Certified seeds of maize (*Zea mays*) NK6240 were surface sterilized with 70% ethanol and washed by sterile distilled water, then dried in shadow open air. The seeds were planted in 30 cm diameter earthen containing sandy loam soil with 54.12% coarse sand, 4% fine sand, 23% silt, 18.39% clay with pH of 7.85, electrical conductivity of 3.64 ds/m, Ca^{++} of 9.8, Na^{+} of 8.6, Mg^{++} of 13.69, K^{+} of 0.81, Cl^{-} of 21.03 HCO_3 of 7.51 and SO_4 of 6.08, along with the total heterotrophic bacterial count of 6×10^6/g soil and cyanobacterial count of 8×10^3/g and CO_2 emission of 12 mg/100 g soil/day. The soil was treated with cow dung manure and two microalgae separately at the dose of 3 g dry powder per kg soil before planting. Completed randomized design with the following six treatments in six replicate was laid out for cultivation under green house conditions, maintained with natural environmental conditions. Every treatment was sprouted with 15 seeds and watered two times in a week. The shoot length and leaves number were recorded at the 50th day and the maize plant height was measured at the 75th day. Levels of nutrients available with

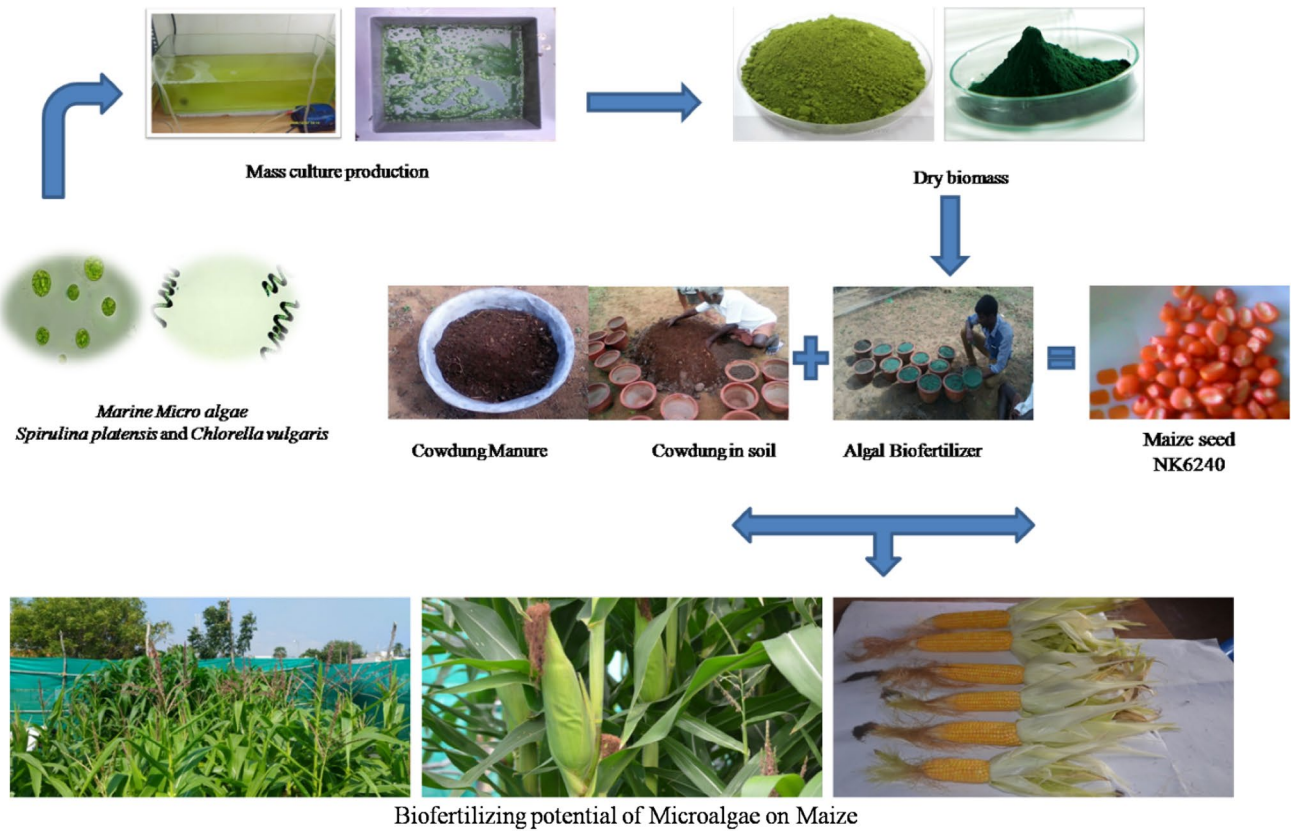


Fig. 1 Proposed model of the present work

the microalgal powder and cow dung manure as well in the soil used were determined as shown in Table 1.

Treatments were as follows:

1. Control
2. Cow dung manure
3. *Spirulina platensis*
4. *Chlorella vulgaris*
5. Cow dung + *Spirulina platensis*
6. Cow dung + *Chlorella vulgaris*

Growth, Yield and Soil Analysis

The plant height and number of leaves were recorded at different growth stages. At the end of the experiment the following parameters viz., plant fresh weight, dry weight, shoot length, root length, and the levels of N, P, K, indoles, phenols, chlorophyll a, b, carotenoids, total sugar and reducing sugar content were analysed by following the standard methods [1, 36, 55, 57]. At the time of harvest, number, weight of maize corn seeds and biochemical parameters (protein, carbohydrate, lipids, total fiber and total sugars) as well as minerals (N, P, K, Fe, Mn and Zn) were determined by following standard methods [10, 12, 19, 37].

Table 1 Levels of nutrients in soil, *S. platensis, C. vulgaris* and cow dung manure used before treatment

Nutrients	Available nutrients (mg/kg)			
	Soil	Cow dung manure	*Spirulina platensis*	*C. vulgaris*
N	17.9	11.304	13.1	12.8
P	13.86	4.636	29	24
K	60.38	5.13	146	138
Fe	3.81	5.134	0.65	1.38
Zn	0.58	8.48	0.25	0.48
Mn	2.06	0.62	18	19

Soil was analysed after the experiment, for pH, electrical conductivity, phosphorus [67], potassium [6], nitrogen [1], CO_2 evolution [26], total heterotrophic bacterial count [6], cyanobacterial count [61].

After harvested the corn seeds from the treated plants the seeds were seeded in the soil and after that the seeds were handpicked measure the length of the germination through the scale.

Statistical Analysis

Data were subjected to analysis of variance and the means were compared using the "Least Significant Differences" test at the 0.05 level [60].

Results

Shoot Length and Number of Leaves in Maize Plant

The effect of microalgal treatment on shoot length and leaf sprouted is shown in Table 2 Treatment of cow dung manure + *S. platensis* exhibited significant increase in the shoot height after 10th, 20th, 30th and 40th days of experiment and the treatments of cow dung manure + *C. vulgaris* showed good results after 20 days, while there was no significant increase in shoot height after 30 and 40 days.

Effect of Microalgae Treatment on the Fresh and Dry Weights (g), Length and Growth of Maize Plant

Fresh Weight and Dry Weight of Maize Plant

Table 3 revealed that the treatment increased fresh weight (32.4–86.7%) and dry weight (21.6–48.6%) of the plant. While the treatment of cow dung + *Spirulina platensis* gave the maximum results of total plant fresh weight and *Spirulina platensis* recorded maximum dry weight also its

Table 2 Effects of microalgae treatment on the shoot length and leaves numbers of maize at different days of sowing

Treatments	Shoot length (cm/plant)					Leaves numbers/plant				
	10 days	20 days	30 days	40 days	50 days	10 days	20 days	30 days	40 days	50 days
Control	9.3	13.6	36.4	39.1	43.8	3.0	5.6	6.1	8.4	10.4
Cow dung	12.6	16.3	39.7	43.1	47.5	3.6	7.6	8.8	10.3	12.4
S. platensis	12.9	17.1	40.6	43.8	48.3	3.8	8.2	9.3	10.9	12.6
C. vulgaris	12.4	16.9	39.2	43.1	47.8	3.4	7.8	8.8	10.6	12.4
C.D + S.P	15.8	26.5	44.7	46.3	51.1	4.2	9.3	11.6	13.8	15.7
C.D + C.V	15.1	24.9	43.1	44.6	48.8	3.9	8.3	9.8	11.7	13.6
LSD 0.05	0.03***	0.006***	0.233 ns	0.006***	0.113 ns	0.000***	0.211 ns	0.051 ns	0.157 ns	0.236 ns

C.W Cow dung, *S.P S. platensis, C.V C. vulgaris, NS* not significant

***Highly significant

Table 3 Effect of microalgae treatment on the fresh and dry weights (g), length and growth of maize plant (cm) after 75 days of sowing

Treatments	Fresh and dry weight (g/plant)								Length and growth of maize plant (cm)			
	Fresh weight (g/plant)				Dry weight (g/plant)				Shoots	Roots	Total	
	Shoot	Root	Whole plant	Increase (%)	Shoot	Root	Whole plant	Increase (%)	Height (cm/plant)	Length (cm/plant)	Length (cm/plant)	Increasing (%)
Control	32.1	9.3	41.4	–	2.8	0.9	3.7	–	40.2	14.3	54.5	–
Cowdung	36.4	18.4	54.8	32.4	3.4	0.9	4.5	21.6	52.1	18.2	70.3	28.9
S. platensis	42.6	15.6	58.2	40.6	3.9	1.1	5.0	35.1	53.8	18.8	72.6	33.2
C. vulgaris	41.8	15.2	57.0	37.7	3.6	0.7	4.8	29.7	52.3	18.3	70.6	29.5
C.W + S.P	48.6	28.7	77.3	86.7	3.4	0.9	5.5	48.6	55.6	22.1	77.7	42.6
C.W + C.V	34.0	31.0	65.0	57	3.6	1.4	5.1	37.8	54.1	21.6	75.7	38.9
LSD 0.05	0.366 ns	0.052 s	0.183 s		0.512 ns	0.004***	0.818 ns		0.006***	0.000***	0.000***	

C.W Cow dung, *S.P S. platensis*, *C.V C. vulgaris*, *NS* not significant

***Highly significant

significantly increased in the growth of length, shoot and root. The weight of the plants was moderately increased with *Spirulina platensis* and *C. vulgaris* treatments. In both dry and fresh weight, the least values were observed in cow dung treated plants.

Length and Growth of Maize Plant

Treatment of cow dung manure + *S. platensis* and cow dung manure + *C. vulgaris* gave the highest increase in plant growth after 10–50 days at the interval of 10 days. Hence, the treatment of cow dung + *S. platensis* was most favorable for growth of the plants during the early stages.

All the treatments caused noticeable increase in total plant height of all experimental sets. Treatment of cow dung + *S. platensis* exhibited better height growth (42.6%) than the treatment of cow dung + *C. vulgaris* (38.9%) and the cow dung manure showed the lower growth rate and it was found to be 28.9% (Table 3).

Effect of Microalgae Treatments on the Levels of Nutrient Composition and PGPR in Maize Plant

N, P, K Content (%) in Plant Shoot, Roots and Whole Plant of Maize

Table 4 displaying the levels of N, P, K in the plant revealed that all the treatments increased the levels of nitrogen (0.57–0.88%), phosphorus (0.38–0.51%) and potassium (1.04–1.37%) in maize plants after 75 days. The maximum increase in nitrogen and phosphorus was observed in cow dung + *S. platensis* treated plants and minimum in cow dung alone treated plants. However, the values of potassium were found to be highest in cow dung treated and least in cow dung + *S. platensis* treated plants.

Plant Growth Promoters: Total Carbohydrate, Indoles and Phenols in Leaves and Roots of Maize Plant

Table 4 revealed that levels of total carbohydrate, indoles and phenols of leaves and root of maize plants increased significantly with the treatments of algae and cow dung manure. The maximum increase was recorded in total carbohydrate in leaves and roots (22.16 and 39.82%), indole content in leaves and roots (2.01 and 1.07 mg/g) and phenols in leaves and roots (1.82 and 1.17 mg/g) in cow dung + *S. platensis* treated plants followed by cow dung + *C. vulgaris*, cow dung, *S. platensis* and *C. vulgaris* treated plants. The minimum values were recorded in control.

Table 4 Effect of microalgae treatments on the levels of Nutrient composition and PGPR in maize plant

Treatments	Nutrients composition in maize plants												Plant Growth Promoters (PGPR) in maize plants					
	N-content (%)				P-content (%)				K-content (%)				Total carbohydrates (% DW)		Indoles (mg/g FW)		Phenols (mg/g FW)	
	Shoot	Root	Whole plant	Increase (%)	Shoot	Root	Whole plant	Increase (%)	Shoot	Root	Whole plant	Increase (%)	Leaves	Root	Leaves	Root	Leaves	Root
Control	0.39	0.26	0.65	–	0.36	0.39	0.75	–	2.7	0.46	3.16	–	20.13	27.33	1.07	1.35	1.17	1.25
Cowdung	0.86	0.36	1.22	0.57	0.54	0.59	1.13	0.38	3.66	0.87	4.53	1.37	21.73	37.35	1.76	1.97	1.58	1.23
S. platensis	0.91	0.35	1.26	0.61	0.63	0.53	1.16	0.41	3.80	0.68	4.48	1.32	21.30	37.72	1.98	2.36	1.76	1.96
C. vulgaris	0.89	0.29	1.18	0.53	0.58	0.55	1.13	0.38	3.64	0.73	4.37	1.21	19.86	37.18	1.83	2.16	1.61	1.72
C.W + S.P	1.08	0.45	1.53	0.88	0.67	0.59	1.26	0.51	3.28	0.92	4.20	1.04	22.16	39.82	2.01	2.41	1.82	1.98
C.W + C.V	1.02	0.42	1.44	0.79	0.63	0.61	1.24	0.49	3.16	1.12	4.28	1.12	21.93	39.65	1.96	2.39	1.79	1.84

Chlorophyll a and b, Carotenoids, Total Sugars and Reducing Sugars in Leaves of Maize Plant

Figure 2 exhibits the levels of photosynthetic pigments, total and reducing sugar in the plant. The levels of pigments, such as chlorophyll a, b, carotenoids were high in the treatments of cow dung + *S. platensis* (1.32, 0.873 and 0.617 mg/g respectively) as well as cow dung + *C. vulgaris* (1.292, 0.731 and 0.587 mg/g), while the least concentrations were noticed in control (0.314, 0.183 and 0.213 mg/g).

Levels of total sugars and reducing sugars were significantly increased when maize plant were treated with cow dung alone as 0.7 mg/g, and reasonable increase was noted in cow dung + *S. platensis* (0.293 and 0.296 mg/g) as well as Cow dung + *C. vulgaris* (0.252 and 0.264 mg/g). The minimum quantities were observed in plants treated with *S. platensis* (0.254 and 0.283 mg/g) and/or *C. vulgaris* (0.218 and 0.225 mg/g).

Effect of Microalgal Treatments on Soil Characteristics, Macronutrients and Micronutrients (mg/kg) and Its Microbial Population at Flowering Stage of Maize

The physical, chemical and biological analysis of the soil before and after the addition of algae at flowering stage are shown in Tables 5 and 6. There was a significant increase in available micro and macro nutrients and increase in soil micro flora (bacteria and cyanobacterial counts) and weak carbon dioxide emission in the treatments.

Yield Characteristics of Maize, Biochemical Composition of Corn Cobs and Mineral Contents (mg/g) in Corn Cobs

Seed Yield Characters of Maize After Harvest

Table 7 demonstrated that there was an increased yield of 2.375 and 2.357 kg in the treatment with cow dung + *S. platensis* and cow dung + *C. vulgaris* without affecting seed yield characters. The weight of corncobs was found to be higher in all the treated plants than control.

Biochemical Composition of Maize Seed

Table 7 indicated that the levels of protein, carbohydrate, lipids, fiber, total sugar were noted high in the plants treated with cow dung + *S. platensis* (12.73, 84.03, 4.5, 8.2 and 0.779 mg/g respectively) and in Cow dung + *C. vulgaris* (12.51, 85.02, 5.1, 7.8 and 0.81 mg/g). The biochemical composition of the seeds was found to be in decreasing order of the plants treated with micro algae mixed

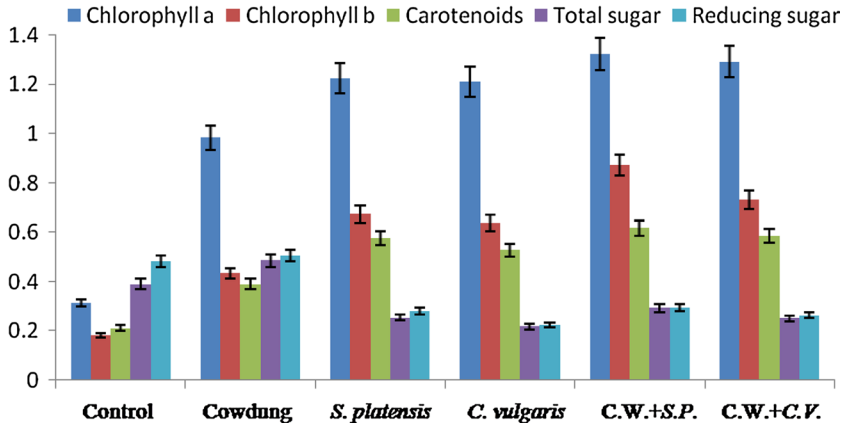


Fig. 2 Effect of microalgal fertilizers on Chlorophyll a, b, carotenoids, total sugars, reducing sugars (mg/g) in leaves and roots of maize plant at flowering stage. *C.W* Cow Dung, *S.P S. platensis, C.V C. vulgaris*

Table 5 Effect of microalgal treatments on soil characteristics at flowering stage of maize

Treatment	Ph	EC ds/m	Ca^{++}	Na^{+}	Mg^{++}	K^{+}	CO_3^{-}	Cl^{-}	HCO_3^{-}	SO_4
Control	7.91	4.36	11.8	9.3	15.1	0.92	–	21.03	7.72	6.09
Cowdung	8.19	4.39	12.5	9.5	15.4	0.94	0.23	21.12	7.84	6.12
S. platensis	8.32	4.42	12.6	9.5	15.6	0.96	–	21.09	7.64	6.14
C. vulgaris	8.36	4.46	12.9	9.4	15.8	0.97	–	21.08	7.34	6.23
C.W + S.P	8.35	4.45	13.4	9.7	15.8	0.99	0.32	21.16	7.97	6.30
C.W + C.V	8.34	4.42	13.6	9.6	15.5	0.96	0.29	21.14	7.87	6.26

Table 6 Effect of microalgal treatments on available macronutrients and micronutrients (mg/kg) and its microbial population

Treatments	Macronutrients and micronutrients in the soil (mg/kg)						Microbial counts and CO_2 emission in the soil		
	N	P	K	Fe	Zn	Mn	Total bacterial count (cfu/10^6/g soil)	Total cyanobacterial count. (cfu/10^6/g soil)	CO_2 evolution (mg/100 g/soil/day)
Control	18.2	13.92	60.43	3.92	0.78	2.09	7.00	9.00	13.00
Cowdung	18.6	14.9	60.63	4.12	1.32	2.17	11.00	11.00	16.00
S. platensis	18.9	14.24	60.86	4.32	1.43	2.26	16.00	19.00	26.00
C. vulgaris	18.8	14.22	60.82	4..46	1.83	2.31	19.00	17.00	27.00
C.W + S.P	19.2	14.29	60.98	4.58	1.72	2.38	21.00	24.00	34.00
C.W + C.V	19.0	14.27	60.94	4.52	1.96	2.91	23.00	21.00	37.00

cow dung > individual microalgae treated > cow dung alone > control.

Minerals Content in Maize Seeds

Table 7 indicated that the levels of nitrogen, phosphorus, potassium, iron, manganese and zinc were high in seeds of plants treated with cow dung + *S. platensis* (255, 304.3, 330, 5.1, 1.6 and 4.9 mg/g respectively) as well as Cow dung + *C. vulgaris* (252, 303.8, 331, 5.2, 1.7 and 4.7 mg/g). The mineral composition of the seeds was found to be high in the plant treated with mixed microalgae, followed by the plants treated with individual microalgae and cow dung alone.

Physical Characters in Seeds Produced by Maize Under Microalgal Treatments

Physical characteristics of maize such as diameter, length and seed weight are shown in Fig. 3. The diameter, length and weight of the seeds were recorded high (0.9 mm, 1.3 mm and 1.52 g respectively) in the plants treated with cow dung + *S. platensis* and 0.9 mm, 1.2 mm and 1.48 g in the plants treated with cow dung + *C. vulgaris*. The physical characteristics of the seeds were recorded moderate in the plants treated with individual microalgae i.e., *S. platensis* treated (0.8 mm, 1.1 mm and 1.48 g) and *C. vulgaris* (0.8 mm, 1.0 mm and 1.43 g). The physical characteristics of the corn seeds were recorded low level in cow dung alone

Table 7 Yield characteristics of maize, biochemical composition of corn cobs and mineral contents (mg/g) in corn cobs

Treatments	Yield characteristics of maize			Biochemical composition of corn cobs					Mineral contents (mg/g) in corn cobs					
	Total no. of Corn cobs	Wt. of 1 corn cob (g)	Total no. of 15 corn cob yield maize plant (kg/ha)	Protein (mg/g)	Carbo-hydrate (mg/g)	Lipids (mg/g)	Total fiber (mg/g)	Total sugar (mg/g)	N (mg/g)	P (mg/g)	K (mg/g)	Fe (mg/g)	Mu (mg/g)	Zn (mg/g)
Control	15	130.45	1.856	9.4	74.3	4.7	7.3 g	0.64	236	299.6	324.8	4.8	1.0	4.6
Cow dung	15	143.81	2.157	10.3	81.08	3.9	7.6	0.7	240	302	326	4.6	1.3	4.8
S. platensis	15	144.72	2.170	11.6	82.38	4.1	7.8	0.73	253	303	331	4.9	1.5	4.5
C. vulgaris	15	142.18	2.132	11.2	83.11	4.8	6.9	0.78	250	302.1	332	4.8	1.3	4.6
C.W + S.P	15	158.37	2.375	12.73	84.03	4.5	8.2	0.79	255	304.3	330	5.1	1.6	4.9
C.W + C.V	15	157.19	2.357	12.51	85.02	5.1	7.8	0.81	252	303.8	331	5.2	1.7	4.7

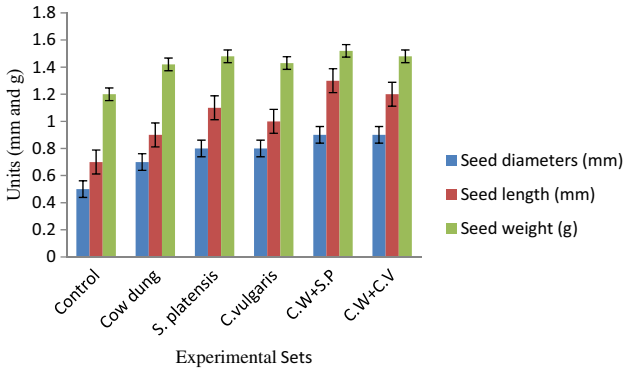
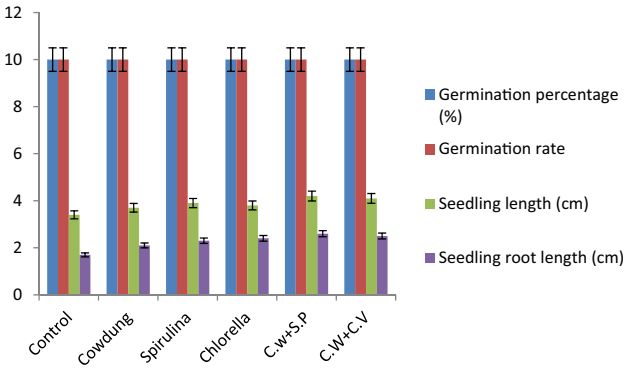


Fig. 3 Physical characters in seeds produced by maize under microalgal treatments. *C.W* Cow dung, *S.P S. platensis, C.V C. vulgaris*



C.W- Cowdung, S.P- ***Spirulina platensis*****, C.V-** ***Chlorella vulgaris***

Fig. 4 Germinability characters in seeds produced by maize under microalgal treatments. *C.W* Cow dung, *S.P S. platensis, C.V C. vulgaris*

treated (0.7 mm, 0.9 mm and 1.42 g) and control (0.5 mm, 0.7 mm and 1.2 g).

Germinability Characters in Seeds Produced by Maize Under Microalgal Treatments

Germination percentage, rate of germination, seedling length and seedling root length in response to different treatments are shown in Fig. 4. The highest values of germination percentage, rate of germination seedling length and seedling root length were recorded to be 10, 10%, 4.2 and 2.6 cm respectively from the plants treated with cow dung + *S. platensis* and 10, 10%, 4.1 and 2.5 cm from the plants treated with cow dung + *C. vulgaris*. The moderate values were recorded from the plants treated with individual microalgae i.e., *S. platensis* (10, 10%, 3.9 and 2.3 cm) and *C. vulgaris* treated (10, 10%, 3.8 and 2.4 cm). The least values were recorded in the seeds from the plants treated with cow

dung (10, 10%, 3.7 and 2.1 cm) and control (10, 10%, 3.4 and 1.7 cm).

Discussion

The present study indicates that cow dung + *S. platensis* andcow dung + *C. vulgaris* have significant potential as biofertilizers to enhance growth and yield of *Maize* plants. These results are in support of earlier works [9, 62]. During the initial growth stages, the increase in number of leaves and plant height was recorded in all the treatments. These results are in agreement with those reported by El Barody et al. [20] and Haroun and Hussein [29]. However, after 60 days of planting, the increase in plant weight was recorded. These results are in accordance with the findings of Faheed and Abd-El Fattah [23]. All the treatments recorded with high levels of nitrogen, potassium and phosphorus in maize plants, similar to the observation made by earlier workers [2, 29, 38, 54, 63]. In all the treatments, the levels of carbohydrate increased in accordance with the reports of previous workers [29, 38].

Dineshkumar et al. [18] have proved the potential of *C. vulgaris* and *S. platensis* as biofertilizer in increasing the yield up to 20.9% in rice, and attributed the beneficial effect to better soil fertility, which is similar to the present finding in maize. The role of nitrogen and phosphorus fertilizers is well known to increase the growth and grain yield in maize production [46, 56]. Increasing the nitrogen fertilizer rate from zero up to 250 kg N/ha significantly enhanced the number of leaves/plant of maize [8]. Similarly, maize plant height and ear length increase with elevated nitrogen Kandil [35]. The enhanced phosphorus level is reportedly increase grain yield, biomass and seed weight of maize [64]. The phosphate solubilizing bacteria is known to increase the supply of P and resulted in the yield improvement due to increment of root system as a source-sink relationship to the reproductive part of plant species including legume crops [41, 48], Höflich et al. [31].

The present study displayed a downward trend of germination when sowing large maize seeds, similar to the finding of Graven and Carter [27]. However, Royo et al. [52] have observed an opposite effect that the yield of durum wheat plants grown from large grains is higher by 16% than that from growth plants with small seeds. They also recorded that large seeds produce greater plot stands but the plants have fewer tillers, leaves and spikes and lesser green area and dry weight than the plots with small seeds. Rukavina et al. [53] have noticed a significantly higher yield from planting larger seeds rather than smaller seeds in barley cultivar. According to Gholizadeh et al. [21] the maize seeds of larger size have high vigour to produce seedlings of better establishment and growth in the field [16].

The present study found statistically significant higher levels of Mg, P and K in maize plants, but with low concentrations of Ca, Mg, Zn, Fe and CO_3 and Na which is well in agreement with the findings of Oshodi et al. [47]. Similarly, Hussaini et al. [32] has observed that Nitrogen fertilizer application up to 60 kg/N/ha significantly increases the concentration of N, P, Mg and K. The low levels of calcium and zinc recorded in this study is also in agreement with the findings of Matilda et al. [40], who have found that cereal are poor in these minerals. However, the observed differences in mineral composition in the plants may be due to genetic and environmental factors such as irrigation frequency, soil composition and fertilizer used [34].

The carbohydrate content varied in maize products such as maize old kernel, fresh kernel, maize flour and maize bran in the present study Ayatse et al. [7] and Ujabadenyi and Adebolu [65] have also reported varied levels of sugars (65.63–70.23%) in maize grown in Nigeria. However, Wilson et al. [68] have recorded higher carbohydrate content of about 72–73% in maize kernel. The percentage of fat obtained from maize in this study is in agreement with other researchers [33, 40] but is different from the findings of Ujabadenyi and Adebolu [65] who have recorded higher fat content ranged from 4.17 to 5.0%. The observed differences may possibly be due to genetical or environmental factors. Crude fibre is the fourth largest chemical present in maize grain after carbohydrate, protein, fat and moisture content. The fibre content obtained in this study is in agreement with the findings of Ajabadenyi and Aebolu [3], who have reported the fibre content ranged from 2.07 to 2.97, for maize grains in Nigeria.

The seed quality determines the vigour of seedlings production. Farahani et al. [25] observed visually more vigorous seedlings from the large seed fraction of wheat, similar to previous reports [22, 30, 51] which obtained a correlation of 0.69 to 0.87 between seedling vigour and seed size in wheat. According to Chastin et al. [15], higher seed vigour of larger seeds is connected with larger nutrient reserves in the seeds; hence the larger seeds produce seedlings with early growth and an increased competitive ability against weeds and pests. Moreover, lower seed vigour in many cultivated species is connected with lower plant yielding [14, 58]. The production of dry matter in plants grown from large seeds is significantly higher than in plants grown from small seeds [44]. Seed germination in wheat depends on seed size which has a greater effect on the germination percentage than emergence index [59]. Germination of seeds is directly dependent on the activity of β-amylase contained therein [43]. The germination, seedling dry weight, seedling vigour and seedling length increase with the increasing seed size in durum wheat [13]. The present study could not confirm this relationship.

Conclusion

The microalgal treatment mixed with cow dung manure increased plant height growth, yield characters, biochemical and mineral components as well as the germinability of the seeds produced. Cow dung + *S. platensis* or cow dung + *C. vulgaris* was proved to be the best treatment to enhance growth of maize plants during the early stages, up to 51.1% after 60 days of planting. The present work has proved the potential of microalgae as biofertilizer for maize crop.

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Compliance with Ethical Standards

Conflict of interest The authors declare that we have no competing interests.

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