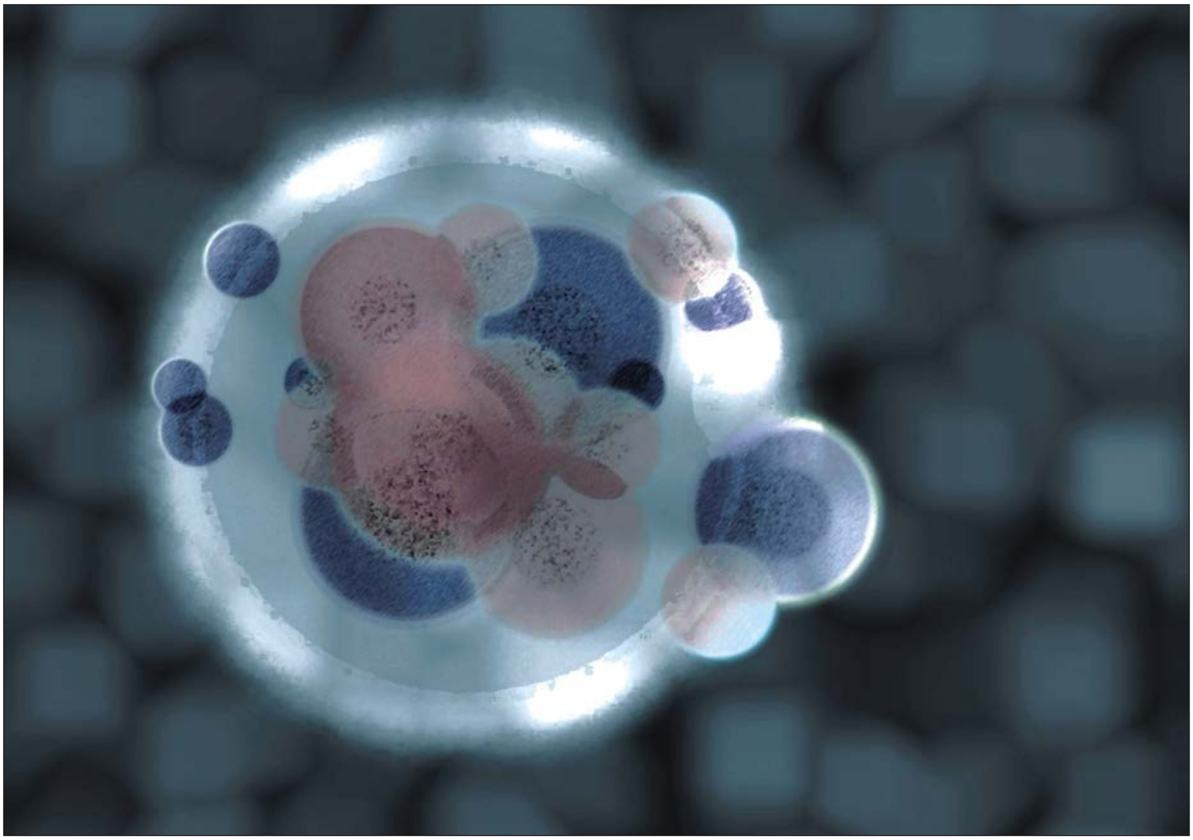

Journal of Biological Sciences

ISSN 1727-3048

OnLine Journal of Biological Sciences 1 (6): 475-479, 2001

Nutritional Status and Growth of Maize Plants as Affected by Green Microalgae as Soil Additives

Mahmoud M. Shaaban
Botany Department, National Research Centre, Dokki, Cairo, Egypt

Abstract: The effect of using dry microalga (*Chlorella vulgaris*) as soil additives on the nutrient status and shoot and root growth of maize plants (*Zea mays* L. var. Triple-hybrid 310) was investigated. Algae were added to the soil before sowing in the rates of 50, 100, 150 and 200 Kg/Fed, in addition to the basic NPK fertilizers. Significant increase in the nutrient taken up by shoots and roots was calculated as a result of adding different alga-levels. Addition of algae has significant increases in root volume, chlorophyll formation, dry weight of shoots and roots as well as plant height. The best treatments were 150 and 200 Kg algae/Fed.

Key words: Maize, green algae, soil additives, nutrient status, growth, chlorophyll

Introduction

From the agricultural viewpoint, soil is the unconsolidated mineral material on the immediate surface of the earth that serves as natural medium for plant growth. Nutrient supply to the roots is governed by nutrient concentrations in the soil solution, nature of the nutrients, soil moisture status and plant's absorption capacity which are related to soil physical and chemical properties (Fageria *et al*., 1997). Green plant materials proved to improve soil characteristics (i.e. soil moisture holding capacity, aeration, cation exchange capacity, growth of the soil microorganisms etc.) providing favorable conditions in the plant growth medium (Al-Gosaibi, 1994; De Boodt, 1975). Green manures were also found to stimulate root growth and produce good yields (Boussiba, 1987; Marschner and Roemheld, 1996; Mandimba *et al*., 1998; Paturde and Patankar, 1998; Buragohain and Medhi, 1999; Kumar *et al*., 1999; Shaaban and Mobarak, 2000).

Dry green algae contain high percentage of macronutrients, considerable amounts of micronutrients and amino acids (El-Fouly *et al*., 1992). They can be cheaply produced on sewage and brackish water and partially substituted the chemical fertilizers to avoid environmental pollution.

This project was carried out to study the effect of dry microalga *Chlorella vulgaris* as soil additives on the root volume, shoot and root nutrient content, chlorophyll formation and consequently growth of maize plants under field conditions.

Materials and Methods

Experimental design and sowing: A field experiment was conducted at Abu-Dahshan area, Ismailia, Egypt during the seasons 1997/1998 and 1998/1999 as Randomized Complete Block Design (RCBD). Soil was prepared and received super mono-phosphate (15.5% P_2O_5) at 200 Kg/Fed (1 Feddan = 0.42 hectare). Soil physical and chemical characteristics and their evaluation according to Ankerman and Large (1974) are shown in Table 1. Seeds were sown in May, 1, 1997 and May, 3, 1998 in 50 cm lines at 25 cm distance and 4-5 cm depth at 2-3 seeds per hole and irrigated. The soil was hoed 2 times (before the 1st and 2nd irrigation). Before the 1st irrigation, the plants were thinned to leave 1 plant per hole.

Dry microalgae (*Chlorella vulgaris*) was added to the soil before sowing. Major components and chemical composition of the dry alga are shown in Table 2. NK at 100 unit N/Fed. as ammonium sulfate (20.6% N) and 90 unit K/Fed. as potassium sulfate (48-52% K_2O). Dry microalgae was added in the rates of 50, 100, 150, 200 Kg/Fed.

After soil preparation and before fertilization, a representative soil sample was taken. The sample was air-dried and passed through a 2.0 mm sieve pores. The following analyses were carried out.

Table 1: Mean values of physical and chemical soil characteristics

Physical characteristics		Nutrient concentrations	
		Exchangeable Macronutrients (mg/100g soil)	
pH	8.2 H	P	1.3C
E.C. (dS/cm)	0.3 A	K	7.7A
$CaCO_3$(%)	1.24B	Mg	32.0C
O.M. (%)	0.51A	Na	6.0A
Sand (%)	87.6	Available Micronutrients (mg/Kg soil)	
Silt (%)	2.0	Fe	5.0B
Clay (%)	10.4	Mn	5.0B
Texture	Sand	Zn	2.0C
		Cu	1.6C

A = deficient, B = low, C = adequate, H = high (Ankerman and Large, 1974)

Mechanical analysis: By using hydrometer method (Bouyoucos, 1951); pH and E.C (electric conductivity) were determined in soil/water extract (1:2.5) (Jackson, 1973); Calcium carbonate content was determined using Calcimeter method (Black, 1965), and organic matter (O.M.) was determined using potassium dichromate method (Walkley and Black, 1934).

Soil phosphorus was extracted using sodium bicarbonate (Olsen *et al*., 1954). Potassium (K) and magnesium (Mg) were extracted using ammonium acetate (Chapman and Pratt, 1978), while Fe, Mn, Zn and Cu were extracted using DTPA (Lindsay and Norvell, 1978).

Fourty days after sowing, maize plants were harvested. Plant height was measured (cm) and then, the plants were divided into shoots and roots, washed with tap water, distilled water (containing 0.01 N HCl) and bidistilled water. Root volume was determined using water displacement in a graduated glass cylinder. Maize plant parts as well as the dry algae were oven dried at 70°C for 24 h. Dry weight of maize plant parts was determined and the plants were ground. 1.0 g of both maize plant parts and dry algae was dry-ashed in a muffle furnace at 550°C for 6 h using 3.0 N HNO_3. The residue was, then, suspended in 0.3 N HCl.

Protein content of the dry algae was calculated as total nitrogen × 6.25. Algae fat content was determined in its ether-extract using method of AOAC (1965). Total carbohydrate content was determined according to DuBois *et al*. (1956).

Chlorophyll content was determined before harvesting in leaves using the portable Hydro N-Tester chlorophyll meter.

Table 2: Major components and chemical composition of dry *Chlorella valgaris*

General Composition		Element content	
Moisture (%) in dry matter at 70°C	46.0	Marco-elements (%)	
Protein (%)	44.6	N	7.1
Fats (%)	7.3	P	0.66
Carbohydrate (%)	12.8	K	2.15
Amino acid composition (g/100g protei)*		Mg	0.34
Arginine	6.9	Ca	.018
Histidine	2.0	Na	0.04
Isoleucine	3.2		
Lucien	9.5	Micro-elements (ppm)	
Lysine	6.4	Fe	860.0
Methionine	1.3	Mn	33.8
Phenylalanine	5.5	Zn	46.9
Threonine	5.3	Cu	7.8
Tryptophan	1.5		
Valine	7.0		

*After El-Fouly *et al*. (1992)

Table 3: Mean values of macro and micronutrients uptake by maize plants as affected with different levels of dry algae as soil additives

Treatment	N	P	K	Mg	Fe	Mn	Zn
Shoot uptake (mg/plant)							
Control (NPK)	260	23	610	56	2.13	0.38	0.29
+ 50 Kg algae/Fed.	300	25	640	59	2.18	0.33	0.21
+ 100 Kg algae/Fed.	320	30	750	67	2.76	0.49	0.33
+ 150 Kg algae/Fed.	380	35	830	71	2.86	0.52	0.42
+ 200 Kg algae/Fed.	380	40	960	82	2.94	0.48	0.40
Correlation (r)	0.969	0.991	0.984	0.981	0.937	0.762	0.80
Root uptake (mg/plant)							
Control (NPK)	110	6.1	55	20	7.68	0.24	0.17
+ 50 Kg algae/Fed.	140	11	64	30	12.02	0.33	0.17
+ 100 Kg algae/Fed.	170	15	85	42	14.91	0.57	0.32
+ 150 Kg algae/Fed.	220	19	116	52	27.39	0.59	0.28
+ 200 Kg algae/Fed.	200	19	118	50	28.08	0.65	0.41
Correlation (r)	0.925	0.965	0.971	0.952	0.961	0.950	0.908
Total uptake (mg/plant)							
Control (NPK)	370	29.1	665	76	9.81	0.62	0.46
+ 50 Kg algae/Fed.	440	36	704	89	14.20	0.66	0.38
+ 100 Kg algae/Fed.	470	45	835	109	17.67	1.06	0.65
+ 150 Kg algae/Fed.	600	54	946	123	30.25	1.11	0.70
+ 200 Kg algae/Fed.	580	59	1078	132	31.02	1.14	0.81
Correlation (r)	0.943	0.996	0.988	0.992	0.964	0.921	0.914

Table 4: Uptake increase (% over control) of macro- and micronutrients by maize plants as affected with different levels of dry algae as soil additives (mean values)

Treatment	N	P	K	Mg	Fe	Mn	Zn
	Shoot						
Control (NPK)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+ 50 Kg algae/Fed.	15.3	8.7	4.9	5.3	2.3	0.00	0.00
+ 100 Kg algae/Fed.	25.0	30.4	22.9	19.6	29.6	28.9	13.8
+ 150 Kg algae/Fed.	50.0	52.5	36.0	26.8	34.3	36.8	44.8
+ 200 Kg algae/Fed.	50.0	73.9	57.3	46.4	38.0	26.3	37.9
	Root						
Control (NPK)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+ 50 Kg algae/Fed.	27.3	80.3	16.3	50.0	56.5	37.5	0.00
+ 100 Kg algae/Fed.	54.5	145.9	54.5	110	94.1	137.5	88.2
+ 150 Kg algae/Fed.	100.0	211.4	110.9	160	256.6	145.8	64.7
+ 200 Kg algae/Fed.	81.0	211.4	114.5	150	265.6	170.8	141.2
	Total						
Control (NPK)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+ 50 Kg algae/Fed.	18.9	23.7	5.9	17.1	44.8	6.4	0.0
+ 100 Kg algae/Fed.	27.0	54.6	25.5	43.4	80.1	6.45	41.3
+ 150 Kg algae/Fed.	62.7	85.5	42.2	61.8	208.3	70.9	52.2
+ 200 Kg algae/Fed.	56.8	102.7	62.1	73.6	216.2	79.0	76.1

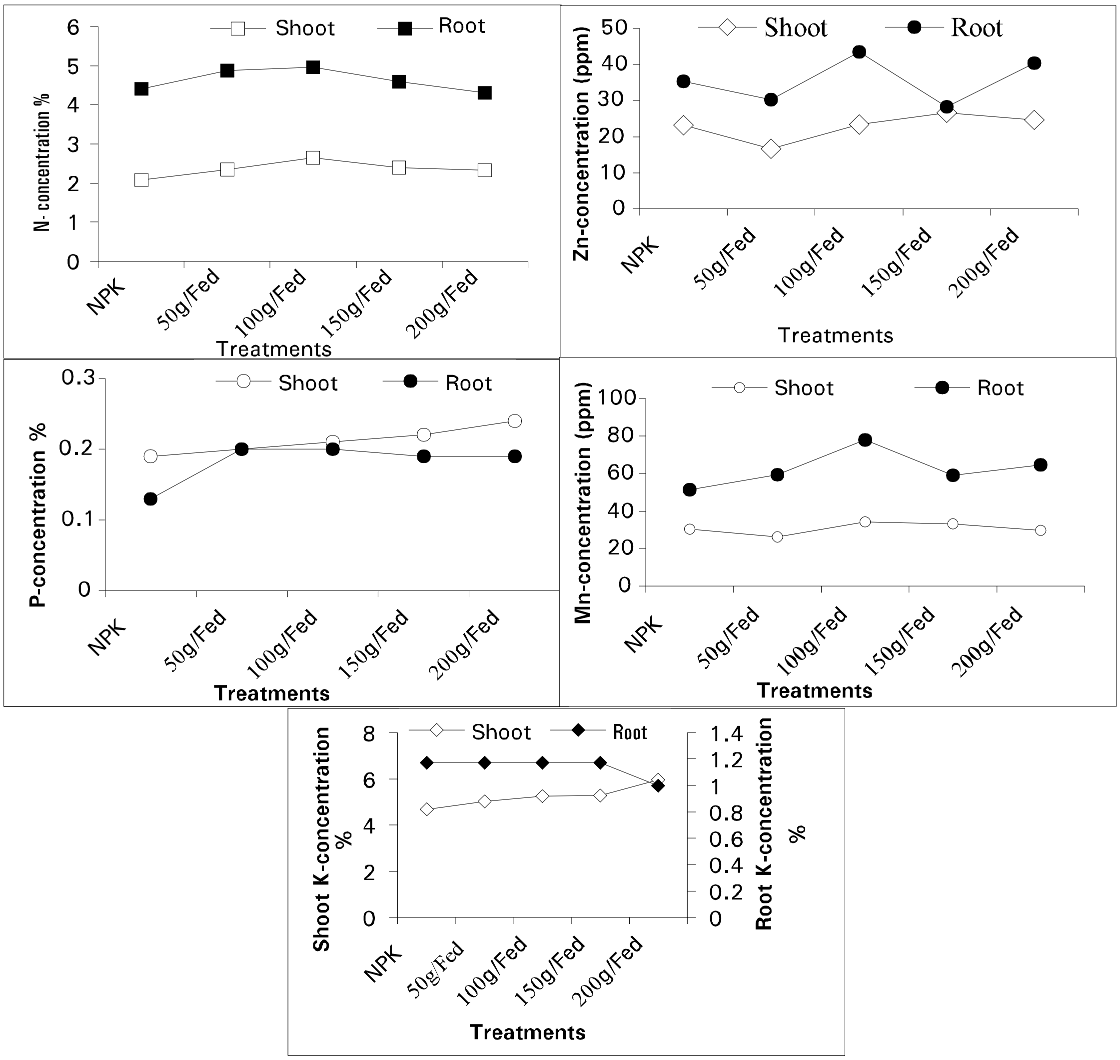

Fig. 1: Mean values of nitrogen, phosphorus, potassium, iron, manganese and zinc concentrations in shoot and roots of maize plants as affected by dry algae as soil additives

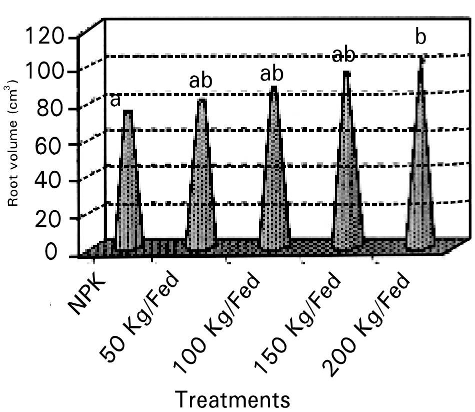

Fig. 2: Maize root volume (cm^3) as affected by different dry algae levels as soil algae additives (columns with same letter are not significantly different, p = 0.05)

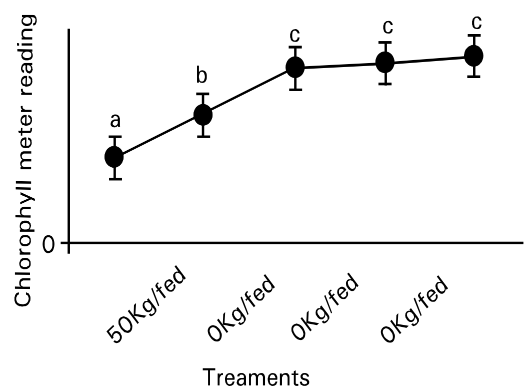

Fig. 3: Chlorophyll-meter readings of maize levesa as affected by levels as soil additives (values with same letter are not significnatly different, p = 0.05)

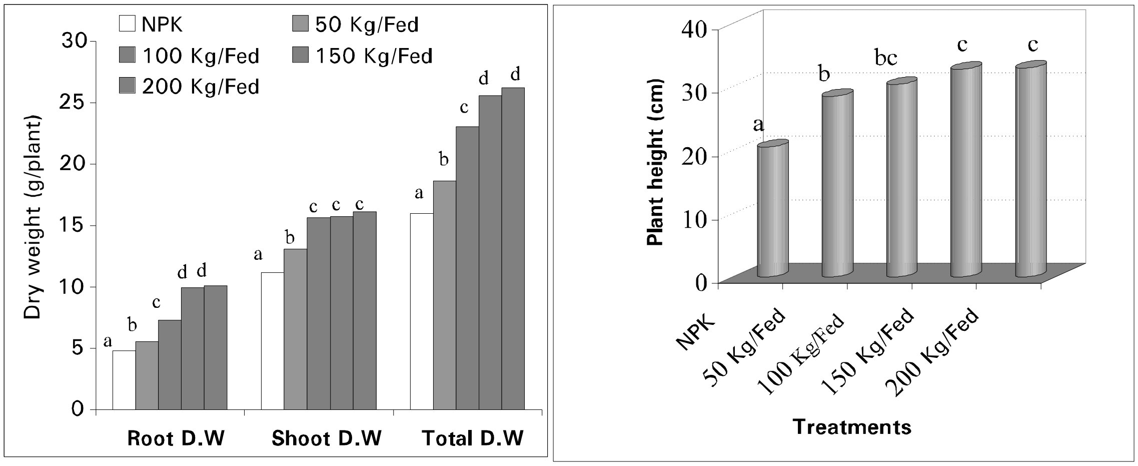

Fig. 4: Mean dry weight and plant height of maize plants as affected by different algae levels as soil additives (columns with same letters are not significnatly different, p = 0.05)

Total nitrogen content of maize plant parts and dry algae was determined using Bauschi digestion and distillation apparatus. Phosphorus was photometrically determined in the dry ashed residue using the Molybdate-Vanadate method and measured using the UVNIS Spectrophotometer. Potassium and Ca were measured in the extract using (Jenway PFP7) Flamephotometer. Mg, Fe, Mn, Zn and Cu were measured using the Atomic Absorption Spectrophotometer.
Data were statistically analyzed using Costate Statistical Package (Anonymous, 1989).

Results and Discussion

Nutrient concentrations and uptake: Nutrient concentrations as affected by different levels of dry algae as soil additives are shown in Fig.1. According to Fageria *et al*. (1997), all the determined nutrients were within the adequate range. Phosphorus and micronutrients Fe, Mn and Zn concentrations were slightly increased, especially in roots. This can be explained by the more availability of these nutrients in the root medium as a result of alga additives. The picture is clearer with the nutrient uptake calculations (Table 3, 4). Uptake of all nutrients by shoots and roots were increased. Highly significant positive correlations were found between the increased levels of alga additives and nutrient uptakes. As the high soil pH (which is characteristic for most of the Egyptian soils), algae additives can serve as a soil conditioner improves the physical and chemical characteristics of the soil rendering better nutrient availability. Shaaban and Mobarak (2000) obtained similar results with faba bean plants. Amino acids-containing algae can also act as phytosiderophores facilitating the absorption of micronutrients by the roots (Marschner and Roemheld, 1996).
A direct reason for increasing uptake of nutrients is the significant increases in the root volume caused by adding different levels of dry algae (Fig. 2), which plays a good role in increasing the absorption surface to different nutrients. As the nutrient status of the shoots were improved, chlorophyll formation rate in the leaves was significantly increased (Fig. 3) and together led to more biosynthesis and biomass accumulation.

Growth: Growth expressed in g/plant and plant height is shown in Fig. 4. Both root and shoot dry weight and consequently total dry weight of the plants was found to increase significantly with the addition of increased alga levels. This was also true for the plant height records. The best treatments were 150 and 200 Kg algae/Fed. Increase in dry weight accumulation as well as plant height is a result of improving the nutrient status in the plant tissues caused by the presence of alga material in the root medium. Similar trends were found by Al-Gosaibi (1994) and Shaaban and Mobarak (2000).
It can be concluded that dry microalgae as soil additives improve plant nutrient status, which, in turn enhances all the physiological reactions that lead to a good growth. A quantity of 100-150 Kg dry algae/Fed can improve soil physical and chemical characteristics and save the addition of secondary and microelements required for a good yield. Furthermore, use of such cheap material as a soil additives can improve soil fertility, plant nutrient status, save costs of secondary and micronutrients required for obtaining good yields and leads to less environmental pollution.

Acknowledgement

The author wishes to thank the staff members of the program "Micronutrients and Plant Nutrition Problems" and its coordinator Prof. Dr. Mohamed M. El-Fouly for their help in the course of the study.

References

AOAC., 1965. Official Methods of Analysis. 10th Edn., Association of Official Agricultural Chemists, Washinton, DC., pp: 316.

Al-Gosaibi, A.M., 1994. Use of algae as a soil conditioner for improvement of sandy soils in Al-Ahsa, Saudi Arabia. J. Agric. Sci. Mansoura Univ., 19: 1877-1883.

Ankerman, D. and L. Large, 1974. Soil and Plant Analysis. A & L Western Agricultural Laboratories Inc., New York, USA.

Anonymous, 1989. CoStat Statistical Package. Cohort Software Corp., Berkeley, CA., USA.

Black, C.A., 1965. Methods of Soil Analysis. 1st Edn., American Society Agronomy, Madison, WI., USA.

Boussiba, S., 1987. Anabaena Azollae as Nitrogen Biofertilizer. In: Algal Biotechnology, Barking, S.T. (Ed.). Elsevier, UK., pp: 169-178.

Bouyoucos, G.J., 1951. A recalibration of the hydrometer method for making mechanicBouyoucos, G.J.,al analysis of soils. Agron. J., 43: 434-438.

Buragohain, S.K. and D.N. Medhi, 1999. Green manuring in combination with nitrogen on producing of sugarcane. Indian Sugar, 48: 923-926.

Chapman, H.D. and P.F. Pratt, 1978. Methods of Analysis for Soils, Plants and Waters. 1st Edn., University of California Press, Berkeley, CA., USA.

De Boodt, M., 1975. Use of soil conditioners around the world. Soil Sci. Soc. Am. Spec. Publ., 7: 1-12.

DuBois, M., K.A. Gilles, J.K. Hamilton, P.A. Rebers and F. Smith, 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem., 28: 350-356.

El-Fouly, M.M., F.E. Abdalla and M.M. Shaaban, 1992. Multipurpose large scale production of microalgae biomass in Egypt. Proceedings of the 1st Egyptian-Italian Symposium on Biotechnology, November 21-23, 1992, Assuit, Egypt, pp: 305-314.

Fageria, N.K., V.C. Baligar and C.A. Jones, 1997. Growth and Mineral Nutrition of Field Crops. 2nd Edn., Marcel Dekker, New York, Pages: 624.

Jackson, M.L., 1973. Soil Chemical Analysis. 1st Edn., Prentice Hall Ltd., New Delhi, India, Pages: 498.

Kumar, V., B.C. Ghosh and R. Bhat, 1999. Recycling of crop wastes and green manure and their impact on yield and nutrient uptake of wetland rice. J. Agric. Sci., 132: 149-154.

Lindsay, W.L. and W.A. Norvell, 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J., 42: 421-428.

Mandimba, G.R., G.D. Okomba and J. Pandzou, 1998. Nodulated legumes as green manure: An alternative source of nitrogen for non-fixing and poor-fixing crops. Int. J. Trop. Agric., 16: 131-145.

Marschner, H. and V. Roemheld, 1996. Root-Induced Changes in the Availability of Micronutrients in Rhizosphere. In: A Plant Roots the Hidden Half, Waisel, Y., A. Eshel and U. Kafkafi (Eds.). Marcel Dekker Inc., New York, Basel, Hong Kong, pp: 557-579.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular No. 939, United States Department of Agriculture, Washington, DC., USA., pp: 1-18.

Paturde, J.T. and M.N. Patankar, 1998. Effect of green manuring with *Sesbania rostrata* and *Sesbania aculeata* as well as levels of nitrogen on yield of transplanted paddy variety SKL-7. Agric. Sci. Digest, 18: 213-216.

Shaaban, M.M. and Z.M. Mobarak, 2000. Effect of some green plant material as soil additives on soil nutrient availability, growth, yield and yield components of faba bean plants. J. Agric. Sci. Mansoura Univ., 25: 2005-2016.

Walkley, A. and I.A. Black, 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37: 29-38.