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EFFECT OF FERTILIZATION WITH *Azotobacter* AND HORNWORT (*Ceratophyllum demersum* L.) ON GROWTH PARAMETERS OF EGGPLANT (*Solanum melongena* L.)

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Abstract

Field experiment was conducted in a farm of Najaf governorate during 2018-2019 season, to study the effect of different concentrations of Azotobacter and hornwort on growth parameters of Eggplant (Solanum melongena L.). The experiment included 6 treatments concerning in three different concentrations of Azotobacter (0, 5 and 10 g·100 ml^{-1} d·w) and two levels of hornwort (0 and 5 T·Ha^{-1}).
The use of Azotobacter had an increasing effect with concentration 10g·100ml $^{-1}$ on all vegetative growth parameters and carbohydrate (plant length, leaves number, shoot dry weight, stem diameter, total chlorophyll in leaves and total soluble carbohydrate in leaves) compared with control treatment (sprays with distilled water) which gave the least means values. Interaction between factors reveal a significant effect in all vegetative growth parameters and carbohydrate.
Hornwort addition with level 5 T·Ha^{-1} had a significant effect on all vegetative growth parameters compared with the control treatment. Interaction between two factors gave a significant effect on all vegetative growth and carbohydrate.
10g·100 ml^{-1} of Azotobacter had a significant effect on all fruit growth parameters (fruit numbers, diameter and length) compared with control treatment which gave the least means. Hornwort addition with level 5 T·Ha^{-1} had a significant effect on all fruit growth parameters compared with control treatment. Interaction between two factors gave a significant effect on all fruit growth parameters.

***Key words:** Eggplant, Azotobacter, Hornwort.*

INTRODUCTION

Eggplant (*Solanum melongena* L.) is a warm season crop. It requires a long and warm growing season for successful production (Sukprakarn et al., 2005). It is nutritious, being low in calories, fat, sodium and is a non-starchy. It contains a large volume of water. It is good for balancing diets that are heavy in protein and starches. It is high in fiber and provides additional nutrients such as potassium, magnesium, folic acid, vitamin B6 and A (Praça et al., 2004). Well-drained, sandy loam soils are ideal for eggplant production (Bliss et al., 2004). The United Nations FAO reported that the total areas cultivated by eggplant in the world reached 1,847,787 ha with a productivity of 55,197,878 tons, while, the total cultivated areas in Iraq reached 8,660 hectares with a productivity of 136,749 tons (FAO, 2021).
In recent years, bio-fertilizers have emerged as an important component of the integrated nutrient supply system and hold a great promise to improve crop yield through environmentally better nutrient supplies (Marozsán et al., 2005).
Azotobacter belongs to family Azotobacteriaceae, aerobic, free living, and heterotrophic bacteria. *Azotobacter* are present in neutral or alkaline soils and *A. chroococcum* is the most commonly occurring species in arable soils. *A. vinelandii, A. beijerinckii, A. insignis* and *A. macrocytogenes* are other reported species, the amount of *Azotobacter* rarely exceeds of 10^4-10^5 CFU·g^{-1} of soil due to lack of organic matter and presence of antagonistic microorganisms in soil (Subba, 2001).
Azotobacter sp. has “Nitrogenase” activity, which mediates the conversion of atmospheric nitrogen (N_2) into ammonium. Bio fertilizers improve the quantitative and qualitative features of many plants (Yosefi et al., 2011).
Ceratophyllum demersum L. (coontail or hornwort) is a completely submersed plant and commonly seen in ponds, lakes, ditches, and quiet streams with moderate to high nutrient

levels (Johnson et al., 1995). It does not produce roots, instead it absorbs all the nutrients it requires from the surrounding water. If it is growing near the lake bottom, it will form modified leaves, which it uses to anchor to the sediment. However, it can float free in the water column and sometimes forms dense mats just below the surface. Les (1986) indicated that the habitat preferences of *C. demersum* are at pH 7.4, with a range extending from 5.9 to 9.4, and in alkaline nutrient-rich sites. In recent years, the use of natural seaweed as fertilizer has allowed for partial substitution of conventional synthetic fertilizer (Zodape et al., 2010).

Thus, the aim of the experiment was to demonstrate the effect of addition of *Azotobacter*, hornwort and their interactions to determine the best focus on improving plant growth of eggplant plant.

MATERIALS AND METHODS

An experiment was conducted during the growing season of 2018/2019 in Najaf governorate. The experiment design was factorial within randomized complete block design (R.C.B.D.) The experiment included 6 treatments i.e. three concentrations of *Azotobacter* (0, 5 and 10 g·100 ml^{-1} d.w.) and two concentrations of Hornwort (0 and 5 T·Ha^{-1}) The aquatic plant (*C. demersum*) biomass used in this study was collected from the Kufa river. Samples were washed with tap water to remove soils and other impurities.

Planting seedlings in 1/4/2018, distance between plants (50) cm. Irrigation was done by dripping system.

Cultural practices were done equally and when it is considered necessary e.g. cultivation, weeding, etc. as mentioned in (Matlob, 1989).

Least significant difference (L.S.D.) test was used to compare means when it is considered significant at probability of 0.05 (Al-Rawi & Khalaf-Allah, 2000).

Studied parameters

Growth measurements were taken as follows:

1. Vegetative growth parameters included the following:

1.1. Plant length (cm);

1.2. Leaves number (leaf·$plant^{-1}$);

1.3. Shoot dry weight (g). Shoot was taken and weighed, then dried in the electric oven at a degree of 65-70°C for a period of 48-72 hours till the weight remains constant (Al-Sahaf, 1989);

1.4. Stem diameter;

1.5. Total chlorophyll in leaves (mg·100 g^{-1}). Acetone was used to extract chlorophyll pigment, according to (Mackinney, 1941);

1.6. Total soluble carbohydrates in leaves (mg·g^{-1}). These were detected according to (Duboies, 1956).

2. Fruit growth parameters included the following:

2.1. Fruits number (fruit·$plant^{-1}$);

2.2. Fruit diameter (cm);

2.3. Fruit length (cm).

RESULTS AND DISCUSSIONS

Results in Table 1 showed that there was a significant difference between the treatments of hornwort on all vegetative growth parameters (plant length, leaves number, shoot dry weight, stem diameter, total chlorophyll in leaves and total soluble carbohydrate in leaves) were 74.1cm, 41.03 leaf·$plant^{-1}$, 86.5 g, 2.166 cm, 19.976 mg·100 g^{-1} and 2.86 mg· g^{-1}, respectively compared with control treatment (without addition of hornwort) which gave the least means were 62.01 cm, 54.416 leaf·$plant^{-1}$, 86.5 g, 2.166 cm, 19.976 mg·100 g^{-1} and 2.86 mg g^{-1}, respectively.

Azotobacter had an increasing effect with con. 10 g.100 ml^{-1} on all vegetative growth parameters (plant length, leaves number, shoot dry weight, stem diameter, total chlorophyll in leaves and total soluble carbohydrate in leaves) which gave the highest values 74.41cm, 40.05 leaf·$plant^{-1}$, 88.35 g, 2.135 cm, 19.33 mg·100 g^{-1} and 2.705 mg·g^{-1}, respectively compared with treatment (without addition of hornwort) that gave the lowest values 59.59 cm, 27 leaf·$plant^{-1}$, 55.335 g, 1.87 cm, 18.8 mg·100 g^{-1} and 2.555 mg·g^{-1}, respectively.

The interaction between hornwort and *Azotobacter* treatments showed significant differences on all vegetative growth parameters (plant length, leaves number, shoot dry weight, stem diameter, total chlorophyll in leaves and total soluble carbohydrate in leaves). Treatment of 5 T·Ha^{-1} hornwort and 10 g·100 mL^{-1} of

Azotobacter gave the largest values, 80.67 cm, 47.9 leaf·plant^{-1}, 113.3 g, 2.32 cm, 20.21 mg·100 g^{-1} and 2.898 mg· g^{-1}, respectively, while the treatment of 0 hornwort and 0 g·100 mL^{-1} of *Azotobacter* gave the lowest values, 50.61 cm, 20 leaf·plant^{-1}, 39.67 g, 1.72 cm, 17.81 mg·100 g^{-1} and 2.301 mg· g^{-1}, respectively.

Table 1. Effect of fertilization with *Azotobacter* and hornwort on vegetative growth parameters and carbohydrate

Treatments		Concentration	Plant length (cm)	Leaves number (leaf·plant^{1})	Shoot dry weight (g)	Stem diameter (m)	Total chlorophyll in leaves (mg·100 g^{-1})	Total soluble carbohydrate in leaves(mg·g^{-1})
Hornwort (T.Ha^{-1})		0	62.01	27.1	54.416	1.863	18.04	2.438
		5	74.1	41.03	86.5	2.166	19.97	2.86
L.S.D A (0.05)			1.487	1.581	3.94	0.095	0.03	0.01
Azotobacter (g·100 mL^{-1})		0	59.59	27	55.335	1.87	18.8	2.555
		5	70.61	35.15	67.69	2.04	18.9	2.688
		10	74.41	40.05	88.35	2.135	19.33	2.705
L.S.D B (0.05)			1.821	1.937	4.83	0.117	0.084	0.012
Hornwort (T·Ha^{-1} × *Azotobacter* (g·100 mL^{-1})	0	0	50.61	20	39.67	1.72	17.81	2.301
		5	67.26	29.1	60.18	1.92	17.87	2.502
		10	68.16	32.2	63.4	1.95	18.45	2.512
	5	0	68.57	34	71	2.02	19.79	2.81
		5	73.06	41.2	75.2	2.16	19.93	2.874
		10	80.67	47.9	113.3	2.32	20.21	2.898
L.S.DAB (0.05)			2.576	2.739	6.83	0.166	0.119	0.018

Results in Table 2 appeared that there was a significant difference between the treatments of Hornwort on all fruit growth parameters (fruit numbers, diameter and length) were 23.013 fruit·plant^{-1}, 7.436 cm and 15.133 cm, respectively compared with control treatment (without addition of hornwort) which gave the lowest means were 16.773 fruit·plant^{-1}, 6.483 cm and 13.413 cm, respectively.

Table 2. Effect of Fertilization with *Azotobacter* and Hornwort on fruits growth parameters

Treatments		Concentration	Fruit number (fruit·plant^{-1})	Fruit diameter (cm)	Fruit length (cm)
Hornwort (T·Ha^{-1})		0	16.773	6.483	13.413
		5	23.013	7.436	15.133
L.S.D A (0.05)			1.769	0.086	0.141
Azotobacter (g·100 mL^{-1})		0	16.83	6.535	13.965
		5	20.445	6.535	14.28
		10	22.405	7.235	14.575
L.S.D B (0.05)			2.166	0.105	0.172
Hornwort (T·Ha^{-1}) × *Azotobacter* (g·100 mL^{-1})	0	0	13.96	5.90	12.98
		5	17.42	6.73	13.57
		10	18.94	6.82	13.69
	5	0	19.7	7.17	14.95
		5	23.47	7.49	14.99
		10	25.87	7.65	15.46
L.S.D AB (0.05)			3.064	0.149	0.244

Azotobacter had an increasing effect with con. 10 g·100 ml^{-1} on all fruit growth parameters (Fruit numbers, diameter and length) which gave the highest values 22.405 fruit·plant^{-1}, 22.405 cm and 14.575 cm, respectively compared with treatment (without addition of hornwort) that gave the least values 16.83 fruit·plant^{-1}, 6.535 cm and 13.965 cm, respectively.

The interaction between hornwort and *Azotobacter* treatments declared significant differences on all fruit growth parameters (Fruit numbers, diameter and length) treatment of (5 T·Ha^{-1} hornwort and 10 g·100 mL^{-1} of *Azotobacter*) gave the highest values, 25.87 fruit·plant^{-1}, 7.65 cm and 15.46 cm respect-tively, while the treatment of (0 hornwort and 0 g·100 mL^{-1} of *Azotobacter*) gave the lowest values, 13.96 fruit·plant^{-1}, 5.90 cm and 12.98 cm, respectively.

The improvement in vegetative characteristics (plant length , leaves number , shoot dry weight, stem diameter, total chlorophyll in leaves and Total soluble carbohydrate in leaves) might be due to the ability of *Azotobacter* to fix atmospheric N which may share its role in increasing the percentage of mineral nutrient in soil. In addition, it increases the surface area of the root hairs followed by increase in average absorption of mineral nutrients (Farida et al., 2003). These bacteria utilize atmospheric nitrogen gas for their cell protein synthesis. This cell protein is then mineralized in soil after the death of the *Azotobacter* cells thereby contributing towards the nitrogen availability of the crop plants thus resulting in a strong symbiotic relationship (Haller & Stople, 1985).

The bio-fertilizer (*Azotobacter*) caused a significant increase in all the fruit growth parameters (fruit numbers, diameter and length) compared with plants having received no *Azotobacter*. The improvement in fruit growth parameters as a result of using *Azotobacter* might be due to the improvement of vegetative growth (plant length , leaves number , shoot dry weight, stem diameter, total chlorophyll in leaves and total soluble carbohydrate in leaves)in the treated plots. Having done the similar work on potato plants, Kumar et al. (2001) reported that increase in yield was due the treatment of soil with *Azotobacter*. Therefore, this treatment caused a high improvement in plant hormones production like auxin, IAA and gibberellins in addition to the vitamins (biotin, folic acid and vitamin B groups).

The improvement in vegetative parameters (plant length, leaves number, shoot dry weight, stem diameter, total chlorophyll in leaves and total soluble carbohydrate in leaves) might be due to use of macrophytes as fertilizer such hornwort and aquaculture purposes is based on their high nutritive value arising from the richness of biochemical constituents such as proteins, carbohydrates and lipids (Rather & Nazir, 2015). Seaweeds contain high macroelement levels (Ca, K, P), especially those from the Phaeophyta (Hong et al., 2007). The content of minerals in the seaweeds used in this research was in general agreement with the typical values for these marine algae from other countries (Kalaivanan & Venkatesalu, 2012; Sivasangari et al., 2010).

The hornwort as fertilizer caused a significant increase in all the fruit growth parameters (fruit numbers, diameter and length) compared with plants non addition hornwort. Adding APB (aquatic plant biomass) derived compost to soil following dewatering and shredding improves soil quality and increases crop yields (Balasubramanian et al., 2013), although the success of the compost in this capacity depends on both the concentration of plant available nutrients (i.e. the C:N:P ratio).

CONCLUSIONS

The addition of *Azotobacter* with concentration 10 g·100 mL^{-1} and hornwort addition with level 5 T·Ha^{-1} had an increasing effect $^{-1}$of eggplant and improving the vegetative, chemical and Fruit growth parameters characteristic. The double interference treatments between *Azotobacter* and hornwort addition had a significant effect on increasing all the studied traits more than single factors.

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