Response of Okra (*Abelmoschus esculentus* (L.) to Different Levels of Hoaglands Solution

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Abstract: This study was carried out to evaluate the performance of Hoaglands solution on the growth of okra (*Abelmoschus esculentus* L.). The experiment comprised of different solution levels: CK (control), 40, 60, 80, and 100 ml/L and set up in Randomized Complete Block Design with five replications. Fresh and dry weight at high levels of Hoaglands solution was highly than with non treated. On the other hand, chlorophyll and carbohydrate content increased in treated plants compared to the control. The highest level of nutrients uptake was found in treatment four and five. Nutrient solution supply significantly decreased soil pH both in rhizopher and non-rhizopher soil. The decrease in soil pH, especially in the rhizopher may increase uptake of nutrient by plants. Results of this study indicated that Hoaglands solution especially at 80 ml/L levels has a profound impact on okra growth of plants.
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Key Words: Okra, hoaglands solution, chlorophyll, nutrients.

1. Introduction

Okra (*Abelmoschus esculentus* [L.] Moench. syn. *Hibiscus esculentus* L.) is a widely cultivated within tropical and subtropical regions, including the Mediterranean Basin, for its immature pods, which are consumed either fresh or after processing (dried, canned or frozen) (Doymaz 2005; Duzyaman 2009). It is a popular vegetable among both the consumers and farmers because it is rich in vitamins and minerals (Oyelade et al., 2003). Although the area under okra has progressively increased during last few years, there is a decreasing trend in its yield per hectare (Anonymous, 2008). It is growing in its popularity due to the increasing awareness of its nutritional value as well as its alternative uses as an oil and protein source. Okra contains proteins, carbohydrates and vitamin C (Lamont 1999, Owolarafe & Shotonde 2004, Gopalan et al. 2007, Arapitsas 2008, Dilruba et al. 2009), and plays a vital role in human diet (Kahlon et al. 2007, Saifullah & Rabbani 2009. Consumption of young immature okra pods is important as fresh fruits, and it can be consumed in different forms (Ndunguru & Rajabu 2004). The green fruits of okra, being rich sources of vitamins, calcium, potassium, and other minerals (Great-workout.com 2009), are produced continuously for several months if the crop is managed properly. In most vegetable crops, appropriate plant spacing could lead to optimized plant growth and fruit yields whereas too high or low plant densities could result in relatively lower yields and poor fruit quality (Paththinige et al., 2008). Nutrient fertilization, in relation to balanced plant nutrition, appeared to be the part and parcel of modern sustainable vegetable production during recent past. This mode of applying fertilizers to the crops has been considered a precious supplement to the application of nutrients to soil system (Fageria et al., 2009). A number of studies highlighted the benefits of fertilization in improving plant growth, crop yield, nutrient uptake and product quality (Naruka and Singh, 1998; Tumbare et al., 1999; Naruka et al., 2000; Alkaff and Hassan, 2003; Chattopadhyay et al., 2003; El-Aal et al., 2010; Zodape et al., 2011).

Hoagland solution has been recommended as a treatment in the integrated plant production due to its being environmentally safe and since it increases the crop yield and quality and also improves the use efficiency of applied nutrients (Savvas,2002; Rouphael et al., 2006; Shiyab et al., 2011). It was used in hydroponic growing system, which may be employed in greenhouses to minimize environmental contamination stemming from fertigation runoff (Savvas, 2002; Rouphael et al., 2006). With this technique, most of the complexities and interferences induced by soil and environmental factors are avoided and better control of the experiment is achieved. Hence, considerable saving of irrigation water and fertilizers may be reconciled with high yields, thereby appreciably increasing the water use efficiency by the crop (Schwarz et al., 1996; Zekki et al., 1996; Rouphael et al., 2005). The nutrient requirements of okra may be determined from the quantities of nutrients removed by the plants throughout their growth cycle in relation to the total biomass yield (i.e. pods harvested and plant parts remaining at the end of harvest). Despite its importance as a vegetable crop, there are currently no data available in the literature concerning the rates of nutrient uptake in relation to biomass production. Moreover, current fertilization practices are largely based on empirical methods, which frequently result in the over application of nutrients (Passam and Rekoumi 2009). This study aimed to evaluate the growth and yield of okra with different levels of hoaglands solution source of nutrients.

2. Materials and Methods:

Seeds of okra (*Abelmoschus esculentus* (L.) Moench.) var. Clemson Spinelss 17042 were obtained locally. The soil used for the pot study was from Jordan University. Relevant soil properties are presented in Table 1. Experiment was conducted in the glasshouse, 2 kg of air-dried soil was weighed and transferred into plastic pots. Okra (*Abelmoschus esculentus* (L.) seedlings were grown over 93 days. All pots were watered and kept at field-capacity moisture throughout the growing seasons. Modified Hoagland Nutrient solution (Hoagland and Arnon, 1950) was supplied to the plants every three days or when needed. The composition of the nutrient solution was 0.5 mM $Ca(NO_3)_2$, 3.1 mM NH_4NO_3, 0.01 mM KH_2PO_4, 50.0 µM KCl, 0.2 µM $CuSO_4$, 12.0 µM H_3BO_4, 0.1 mM $NiSO_4{\cdot}6H_2O$, 2.0 µM $MnSO_4{\cdot}H_2O$, 0.5 µM $ZnSO_4{\cdot}7H_2O$, and 0.2 mM $MgSO_4$. All the treatment groups (different solution levels: 40, 60, 80, and 100 ml/L., along with control (T0), were arranged in a completely randomized design (CRD) with five replicates in each Hoaglands treatments group. Roots and shoots were sampled, and soil samples were collected for analyses.

Growth Parameters and Tissue Analysis

After 93 days, data were collected for shoot fresh weight and root fresh and dry weight. Shoots and roots were dried to a constant weight at 70◦C for 12 hrs and then ground using a small mortar to pass 1.0 mm sieve size. Then samples of 0.5 g of well-mixed, dry and ground plant materials were weighted and ignited in muffle furnace at 550◦C and the ash was dissolved in 5 mL of 2N hydrochloric acid (HCl) for determination of potassium. K was analyzed using flame photometer (Corning, M410; Corning, New York) and iron (Fe) concentration was determined using atomic absorption spectroscopy (Perkin Elmer, 2380; Perkin Elmer, Waltham, MA, USA). Analysis of total nitrogen was performed with Micro-Kjeldahl digestion procedure and crude protein content was determined by multiplying the total nitrogen by a factor of 6.25. The relative water content (RWC) in plant was estimated using the following equation:

$$RWC(\%) = (FW - DW) / (TW - DW) * 100$$

Where, FW is fresh weight, DW is dry weight, TW is turgid weight, DW is dry weight.

The fruits of okra of all the treatments were harvested at marketable stage. Before harvesting the number of fruits per plant was recorded. The number of fruits per plant, fresh and dry weight of fruits of each treatment was recorded just immediately after harvest. The yield per plant was calculated by multiplying the number of fruits per plant and fresh weight per fruit. After harvesting the fresh weight of whole plant (stem and leaf) was weighed. Then the plants were chopped and dried in an oven at 65 °C till a constant dry weight was obtained. For chemical analysis 100 g of fresh plant (stem and leaf) and fruit samples were dried in an oven at 65 °C. Then ground in an electric grinder and made into powder (60 meshed sieves) and stored in air-tight containers. Dried powder of plant and fruit samples was digested following modified micro-Kjeldahl method. N, P and K were determined as described by Jackson (1973).

Chlorophyll and Carbohydrate content

Total Chlorophyll contents of fresh leaves of okra at the onset of flowering were determined spectrophotometically and calculated following Wettstein (1957). The fresh leaves (0.5 cm per sample) were extracted with 80 % acetone at – 4 ^{o}C and the extract centrifuged at 10 000 · g for 5 min and then the absorbance of the supernatant recorded at 645 and 663 nm spectrophotometrically (IRMECO U2020, Geesthacht, Germany). Both chlorophyll a and b were expressed in mg g^{-1} fresh weight following Arnon (1949). Carbohydrates in the fruit were estimated by methods of Sadasivam and Manikam (2005); Murugesan and Rajakumari (2006).

Nutrients determination

Nitrogen was estimated by the Kjeldhal's method (Bremner 1965). The acid digested (10 ml) was taken in Kjeldhal's tubes and the tubes were placed on the Kjeldhal's ammonia distillation unit. Then 5 ml of 40 % NaOH were added to each tube. Boric acid solution (5 ml) was taken in a conical flask with a few drops of mixed indicator. When the distillate was approximately 50 ml, the distillation stopped. The distillate was cooled for 10 min and titrated it with 0.01 N standard H2SO4 till the solution turned pink. Nitrogen was calculated using the following formula:

$$N\% = \frac{(V2 - V1) * N * 0{:}014 * 100}{W}$$

where V2 (volume of standard H2SO4 required to titrate the sample solution), V1 (volume of standard H2SO4 required to titrate the blank solution), N (normality of H2SO4), and W (weight of the sample).

Cations such as K^+ in the digests were determined with a flame photometer (Jenway, PFP-7, Dunmow, UK).

The P in the extract was analyzed by ascorbic acid color development method (Murphy and Riley 1962) using spectrophotometer (Jenway 6100).

Experimental design and statistical analysis

Treatments in the experiment were arranged in a Completely Randomized Design (CRD), with five replicates (a pot in each replicate). Collected data were subjected to the analysis of variance (ANOVA) using SAS program (SAS Inc., Cary, NC, USA). Means were separated according to the Least Significant Difference (LSD) at 0.05 level of probability.

Table 1: Physio-chemical properties of soils collected from the experimental research station of the University of Jordan located in the Middle Jordan Valley

Soil Depth (cm)	Textural Class	Field Capacity (Pv%)	Permanent Wilting Point (Pv%)	EC (dS/m)	pH	Organic matter (%)	Na	K	Ca	Mg
							--------meq/100g------			
0 – 15	silt loam	26	15	1.1	8.32	1.00	0.7	2.01	10.5	3.2
15 – 30	silt clay loam	28	17	1.1	8.30	0.17	0.5	1.60	10.3	3.3
30 – 45	silt loam	29	18	1.1	8.55	0.05	0.8	0.96	10.2	3.1

3. Results and Discussion

Fruits fresh and dry weight and number of fruits /plant

Plants treated with Hoaglands solution had the best growth as compared to the control. The fresh and dry weight of fruits increased significantly in almost all the treatments from treatment one and the highest values were in treatment four and five, respectively (Figure 1 and 2). One of the major causes of low yield in okra is the inadequate information on the application rate of inorganic fertilizer especially compound fertilizer (Awe et al., 2006). If the yield of okra is to be increased, the low fertility soils would require additional nutrients. The highest fruit yield was from application of the Hoaglands solution. Number of fruits/plant was affected by fertilizer treatment (Figure 3). The treatment four had higher number of fruits/plant than the remaining treatments. However, plants from the control had significantly lower number of fruits/plant than from any of the fertilizers.

Leaf chlorophyll and carbohydrate content

The chlorophyll content of leaves was measured using SPAD meter throughout the crop duration. However, results have been showed statistically significant relationship between chlorophyll content of the leaves and the treatments (α =0.05) (Figure 4). The chlorophyll content of leaves was significantly in some treatments. The highest value was at treatment four followed by treatment five. This might be due to better supply of required nutrients to the soil by the application of vermicompost. Carbohydrates are mainly present in the form of mucilage (Liu et al. 2005, Kumar et al. 2009). That of young fruits consists of long chain molecules with a molecular weight of about 170,000 made up of sugar units and amino acids. The main components are galactose (25%) rhamnose (22%), galacturonic acid (27%) and amino acids (11%). The mucilage is highly soluble in water. Its solution in water has an intrinsic viscosity value of about 30%. Significant differences among the treatments were observed as compared to control (Figure 5). Esmailian et al., 2011 reported, that carbohydrate concentration was higher in pots applied with Hoagland compared to control plot fertilizers.

Nutrient composition

The most important elements present in inorganic fertilizers are nitrogen, phosphorus, and potassium which influence vegetative and reproductive phase of plant growth. The uptake of nutrients N, P, K, Fe and Zn was significantly increased with increased solution level (Figure 6 and 7). Plants irrigated with Hoagland solution fruits had the highest contents of N, P and K, compared with the control. The increase of yield of okra due to nutrients such as nitrogen, phosphorus and potassium application of the investigation corroborates other studies (Firoz 2009). The combined effect of these nutrients fertilizers for the increase of yield of okra in the present investigation was found consistent with the findings of Philip et al., (2010). The N concentration of fruits was found significantly higher in all the treatments from treatment one and the maximum value was obtained in treatment four (Figure 6). No significant effect of Hoaglands was observed on P concentration in all treatments. The K concentration of plants was found higher in all the treatments especially in treatment four. The K concentration of fruits though found higher in most of the treatments from control but the differences were not significant. This was contrary to the findings of Obi et al., 2005 who reported, that okra yield and components were lower without the application fertilizer which has nitrogen phosphorus and potassium. Thus, agreeing with the findings from some earlier studies which showed that application of solution is important for enhanced yield of okra (Adediran and Banjoro, 2003). Firoz (2009) reported, that the highest yield (16.73 t/ha) was obtained after the application of 100 kg of liquid nitrogen fertilizer N/ha which was statistically identical to 120 kg N/ha and gave the highest yield of okra. With the application of nitrogen, phosphorus, potassium and main trace elements fertilizers in some treatment resulting in increased pod formation, due to availability of sufficient amount of primary growth elements (Naeem et al,. 2006). Compared to inorganic fertilizers the organic fertilizer having lowered the nutrient content, solubility, and nutrient release rates are typically low than inorganic fertilizers and therefore inorganic fertilizers are more preferred than organic fertilizers (Sanwal et al., 2007).

Influence of Hoagland solution on soil pH levels (Bulk and Rhizosphere soil pH)

The result on Figure 8 shows that the pH of the soil is slightly alkaline ranging from 8.3 – 8.5. There was a slight variation in the pH level after the experiment. Comparing this with pH range, there is a slight decrease in pH with the application of the Hoaglands solution (Figure 8). An appreciable increase in the level of exchangeable cations was equally after increasing nutrient solution levels. The type of nutrient and the amount of nutrients dissolved and the pH of the water source in which the nutrients are dissolved affect the pH of the nutrient solution (Bradley and Marulanda, 2000). If the pH of the nutrient solution is not in the favorable range, it has to be adjusted using a mild acid or a base as required before application. However, this is less feasible under low-input farming and home gardening scenarios. Application of organic materials increased soil pH. This confirms findings of Akande et al. (2003) that application of organic materials could ameliorate slightly acidic tropical soil to improve crop production. The pH of the root solution in the plant bed may also change with time due to relative changes in the uptake rates of individual ions by plants, mainly as a response to changes in plant metabolism. Adjusting the pH of the root solution is not practical and effective particularly in an aggregate type hydroponics system. The pH of the nutrient solution is a major determinant of nutrient uptake by the plants. The most suitable pH range for plants is recognized as 5.8 - 6.5 (Harris, 1988) (different crops will favor a different optimum pH). The pH of the nutrient solution affects the solubility of nutrients, thus controlling the availability of nutrients to the plant (Smith, 2000).

Conclusion

Optimum crop performance is usually limited by inadequate availability of essential nutrients. Fertilizer is one of the most important inputs contributing to crop production because it increases productivity and improves yield quantity and quality. The general low ambient soil nutrient content made the soil suitable for study of responses to fertilizer. Application of organic materials generally resulted in growth which compared favorably with fertilizer alone. Nutrients seemed more available to okra plants with using Hoagland solution. This gave significantly higher fruit yields. The integrated use of Hoagland fertilizer and soil applied recommended chemical fertilizers improved the growth traits of okra plants and enhanced okra yield. The regular testing of such effective this solution and its use, after extensive controlled condition and field scale studies, is recommended for sustainable okra production. Generally, Hoagland solution, lead to increased plant growth (shoot height, shoot number, leaf number, and dry weight).

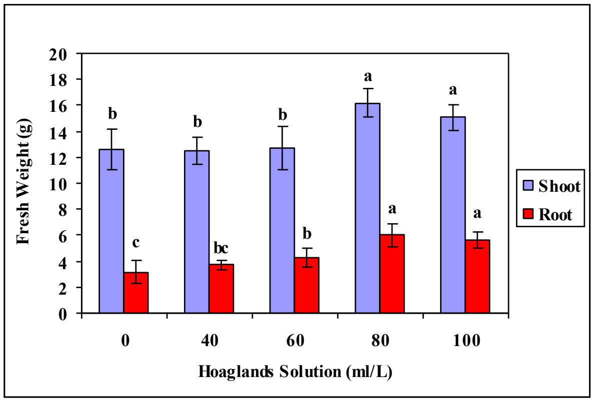

Figure 1: Effect of different levels of Hoaglands solution on fresh weight of okra (*Abelmoschus esculentus* L.).

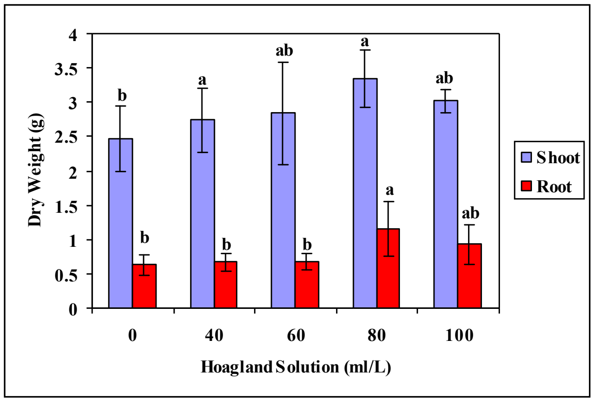

Figure 2: Effect of different levels of Hoaglands solution on dry weight of okra (*Abelmoschus esculentus* L.).

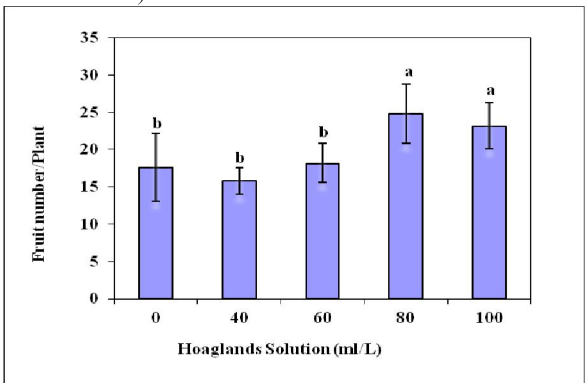

Figure 3: Effect of different levels of Hoagland solution on fruits numbers of okra (*Abelmoschus esculentus* L.).

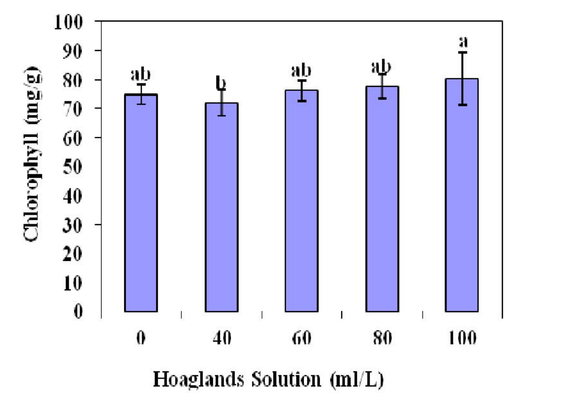

Figure 4: Chlorophyll content (mg/g) in the leaves of okra (*Abelmoschus esculentus* L.) under different Hoaglands solution levels.

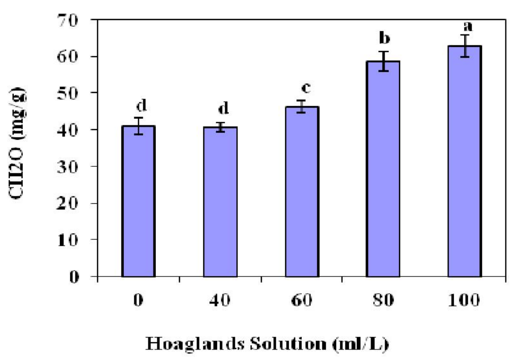

Figure 5: Carbohydrate content (mg/g) in the leaves of okra (*Abelmoschus esculentus* L.) at different levels of Hoaglands solution.

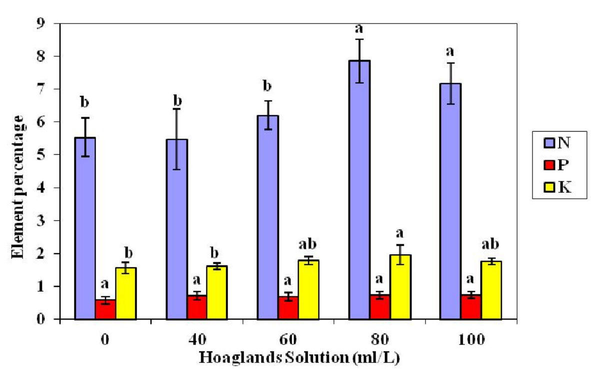

Figure 6: Nutrient percentage in fruit of okra (*Abelmoschus esculentus* L.) at different levels of Hoaglands solution.

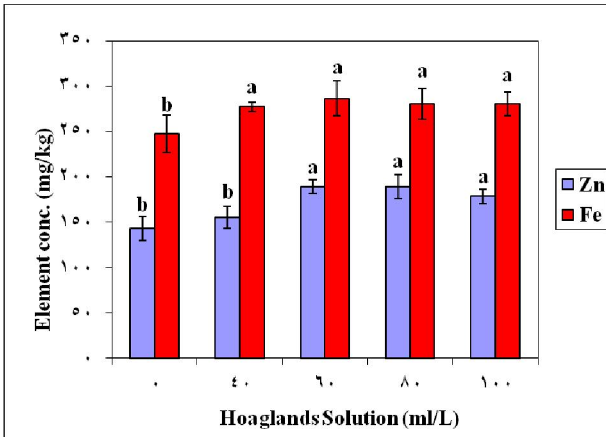

Figure 7: Effect of different levels of Hoaglands solution on zinc and iron of okra (*Abelmoschus esculentus* (L.).

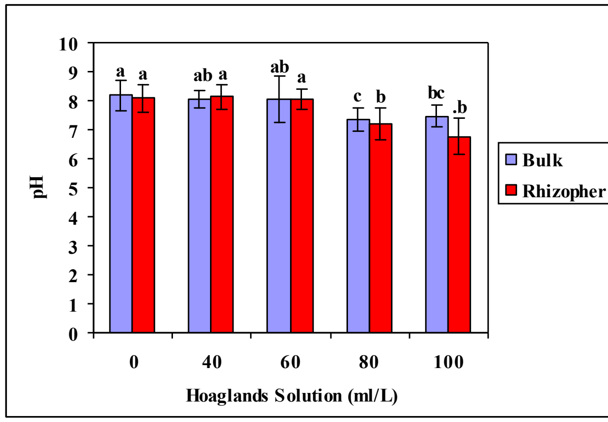

Figure 8: Effect of Hoaglands solution treatments on soil pH of okra (*Abelmoschus esculentus* L.).

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