African Journal of Agricultural Research Vol. 7(7), pp. 1104-1109, 19 February, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1833
ISSN 1991-637X © 2012 Academic Journals

Full Length Research Paper

Effects of bio, mineral nitrogen fertilizer management, under humic acid foliar spraying on fruit yield and several traits of eggplant (*Solanum melongena* L.)

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Accepted 25 January, 2012

To study the effect of nitrogen fertilizer and foliar spraying of humic acid on yield and yield components of eggplant, an experiment was conducted in factorial format based on randomized complete block design with three replications in Astaneh Ashrafiyeh (north of Iran) during 2011 farming year. Factors of experiment consist of humic acid foliar spraying in three levels; H_1: control (without humic acid spraying), H_2: 25 mg/L and H_3: 50 mg/L, and nitrogen fertilizer management with six levels; N_1: control (no nitrogen and no nitroxin), N_2: 40 kg/ha pure nitrogen, N_3: 80 kg/ha pure nitrogen, N_4: roots inoculation with nitroxin, N_5: 20 kg/ha pure nitrogen +roots inoculation with nitroxin and N_6: 40 kg/ha pure nitrogen + roots inoculation with nitroxin. At maturity, fruit yield, number of fruits per square meter, number of branches per plant, plant height, fruit length and fruit width were measured. Results showed that, the effect of foliar humic acid spraying on all measured traits had significant differences at 1% probability level. Also, effect of nitrogen fertilizer management on fruit yield, number of fruit per square meter, plant height, fruit length and fruit width at 1% and on number of branches per plant at 5% was significant. Interaction effect of foliar humic acid spraying and nitrogen fertilizer management on fruit yield at 1% and on number of fruit per square meter, plant height, fruit length and fruit width at 5% was significant and on number of branches per plant was non significant. The highest fruit yield was obtained from use of 50 mg/L humic acid spraying and also from 80 kg/ha nitrogen fertilizer.

Key words: Eggplant, nitrogen, humic acid, yield, Iran.

INTRODUCTION

Eggplant (*Solanum melongena* L.), also known as Aubergine, Brinjal or Guinea squash is one of the non-tuberous species of the night shade family Solanaceae (Kantharajah and Golegaonkar, 2004). The varieties of *S. melongena* L. show a wide range of fruit shapes and colors, ranging from oval or egg-shaped to long club-shaped; and from white, yellow, green through degrees of purple pigmentation to almost black. It is an economically important crop in Asia, Africa and the sub-tropics (India, Central America) and it is also cultivated in some warm temperate regions of the Mediterranean and South America (Sihachkr et al., 1993). Eggplant fruits are known for being low in calories and having a mineral composition beneficial for human health. They are also a rich source of potassium, magnesium, calcium and iron (Zenia and Halina, 2008). Nitrogen is required by plants in comparatively larger amounts than other elements (Marschner, 1995). Nitrogen deficiency generally results in stunted growth and chlorotic leaves caused by poor assimilate formation that leads to premature flowering and shortening of the growth cycle. The presence of N in excess promotes development of the above ground organs with abundant dark green (high chlorophyll) tissues of soft consistency and relatively poor root growth. This increases the risk of lodging and reduces the plants resistance to harsh climatic conditions and to foliar diseases (Lincoln and Edvardo, 2006). Nitrogen (N) fertilizer use has played a significant role in increase of

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Table 1. The results of soil analysis at the experimental sites.

Depth	0-30 cm	Soil texture	Loam clay
Clay (%)	46.58	E.C.(mmhos/cm)	1.32
Silt (%)	29.97	Total nitrogen (%)	0.194
Sand (%)	23.45	P (ppm)	9.1
pH	7.2	K (ppm)	197

crop yield (Modhej et al., 2008). Aminifard et al. (2010), with study responses of eggplant to different rates of nitrogen under field conditions have reported that fertilization with 100 Kg/ha nitrogen resulted in the highest average fruit weight and fruit yield. Pal et al. (2002) have reported that eggplant fruit yield increased with increase in nitrogen up to 187.5 kg/ha. Sat and Saimbhi (2003), observed that increasing the nitrogen significantly delayed flowering of eggplant and increased the number of days taken to fruit setting of eggplant. Excessive application of chemical nitrogen fertilizer can result in a high soil nitrate concentration after crop harvest (Gordon et al., 1993; Jokela and Randall, 1989; Roth et al., 1992). This situation can lead to an increase in the level of nitrate contamination of potable water, because nitrate remaining in the soil profile may leach to groundwater (Singh et al., 1995). A great way to solve these problems is usage of biological nitrogen fixation. The utilization of biological nitrogen fixation method can decrease the use of chemical nitrogen fertilizer (urea), prevent the depletion of soil organic matter and reduce environmental pollution to a considerable extent (Choudhury and Kennedy, 2004). Several bacteria that are associated with the roots of crop plants can induce beneficial effects on their hosts and often are collectively referred to as PGPR (Plant Growth Promoting Rhizobacteria) (Vermeiren, 1999). The biological fixation of nitrogen produced by these organisms can constitute a significant and ecologically favorable condition to soil fertility (Vlassak et al., 1992). Nitroxin is a biological nitrogen fertilizer containing *Azospirillum* and *Azotobacter*. *Azospirillum* belongs to family *Spirilaceae*, heterotrophic and associative in nature. In addition to their nitrogen fixing ability of about 20-40 kg/ha, they also produce growth regulating substances (Arun, 2007). *Azotobacter* belongs to family *Azotobacteriaceae*, aerobic, free living, and heterotrophic in nature. Azotobacters 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 number of *Azotobacter* rarely exceeds of 10^4 to 10^5 g^{-1} of soil due to lack of organic matter and presence of antagonistic microorganisms in soil (Subba, 2001). To improve the organic contents of soils for growing crops there are some applications such as planting rotation, various plough techniques, green fertilizer application and animal fertilizer application. In addition to these practices, utilization of organic-mineral fertilizers in agriculture has increased in recent years (Doran et al., 2003). One of the used organic-mineral fertilizers is humic acid. Humic acid is a commercial product containing many elements which improve the soil fertility and increase the availability of nutrients and consequently increase plant growth and yield. It particularly is used to ameliorate or reduce the negative effect of salt stress. Abd et al. (2005) and Erik et al. (2000), on onion plant and Hafez (2003), on squash reported that humic acid applications led to a significant increase in soil organic matter which in turn improves plant growth and crop production. Magdi et al. (2011), with study effects of bio and mineral fertilizers and humic substances on growth and yield of cowpea have reported that, combination of chemical fertilizer with application of humic substances improve growth and yield of cowpea. The aim of present study was to investigate the influence of foliar application of humic acid and different bio, mineral nitrogen fertilization levels on yield and yield components of eggplant.

MATERIALS AND METHODS

To study effects of humic acid foliar spraying and nitrogen fertilizer management on fruit yield and several traits of eggplant, an experiment in factorial format based on randomized complete block design with three replications *was conducted* in Astaneh Ashrafiyeh township located in 37° 16' latitude and 49° 56' longitude (north of Iran) in 2011. Soil analysis results show that (Table 1), the soil texture was loam clay and pH, 7.2. Factors of experiment consist of humic acid foliar spraying in three levels; H_1: control (without humic acid spraying), H_2: 25 mg/L and H_3: 50 mg/L, and nitrogen fertilizer management with six levels; N_1: control (no nitrogen and no nitroxin), N_2: 40 kg/ha pure nitrogen, N_3: 80 kg/ha pure nitrogen, N_4: roots inoculation with nitroxin, N_5: 20 kg/ha pure nitrogen +roots inoculation with nitroxin and N_6: 40 kg/ha pure nitrogen + roots inoculation with nitroxin). For pure nitrogen preparation was used of urea fertilizer (46% pure nitrogen). Humic foliar spraying was performed in tow stages, at vegetative stage (30 days after planting) and at flowering stage. For root inoculation, nitroxin biofertilizer was sprayed on roots. The experimental field was cleared, ploughed, harrowed and divided into plots, with 10 m^2 areas. Six-week-old eggplant plants were hand-transplanted into well-prepared beds in the field. The spacing between rows was 80 cm and plants were 50 cm. All practical managements included; mulching, weeding and other agronomic treatments were done mechanically. Irrigation was done based on plant requirements. In maturity time, fruit yield, number of fruits per square meter, number of branches per plant, plant height, fruit length and fruit width were measured. The data was analyzed using MSTATC software. Also, the figures were drawing by EXCEL software. The Duncan's multiple range tests (DMRT) was used to compare the means at 5% of significant.

RESULTS AND DISCUSSION

Effect of humic acid foliar spraying

The effect of foliar humic acid spraying on all measured traits had significant differences at 1% probability level (Table 2). Comparison of mean between humic acid

Table 2. Analysis of variance related to the traits of eggplant under humic acid spraying and nitrogen fertilizer management.

Source of variance	df	Fruit yield (t/ha)	Number of fruit (m^2)	Number of branches per plant	Plant height (cm)	Fruit length (cm)	Fruit width (cm)
		MS					
Replication	2	2.740^{ns}	0.557^{ns}	0.116^{ns}	26.611^{ns}	4.139^{ns}	0.382^{ns}
Humic Acid (H)	2	1572.871**	140.690**	1.387**	10365.663**	850.190**	16.496**
Nitrogen Fertilizer (N)	5	933.101**	35.813**	0.236*	1043.718**	139.605**	4.806**
H×N	10	47.013**	2.592*	0.091^{ns}	284.644*	7.025*	0.424*
Error	34	8.862	1.190	0.079	133.497	3.050	0.190
CV%		7.70	5.56	10.03	9.58	6.76	9.19

ns, ** and * respectively: non significant, significant in 1% and 5% area.

Table 3. Comparison of mean about the effects of humic acid spraying and nitrogen fertilizer management.

Treatments	Number of fruit (m^2)	Number of branches per plant	Plant height (cm)	Fruit length (cm)	Fruit width (cm)
Humic acid					
H_1	17.18^{c}	2.50^{b}	94.14^{c}	19.55^{c}	3.75^{c}
H_2	19.06^{b}	2.90^{a}	126.8^{b}	24.81^{b}	4.80^{b}
H_3	22.68^{a}	3.03^{a}	140.9^{a}	33.18^{a}	5.66^{a}
Nitrogen fertilizer					
N_1	17.11^{d}	2.57^{c}	101.3^{c}	19.73^{e}	3.81^{d}
N_2	19.93^{bc}	2.77^{abc}	126.7^{ab}	27.20b^{c}	4.77^{c}
N_3	22.59^{a}	3.04^{a}	130^{a}	30.43^{a}	5.77^{a}
N_4	17.86^{d}	2.71^{bc}	115.2^{b}	22.81^{d}	4.10^{d}
N_5	19.47^{c}	2.84^{abc}	123.3^{ab}	26.23^{c}	4.66 ^{c}
N_6	20.87^{b}	2.91^{ab}	127.3^{a}	28.67^{b}	5.30^{b}

Within each column, means followed by the same letter do not differ significantly at P<0.05.

spraying treatments showed that (Table 3), humic acid application showed a positive and significant effect on all studied traits. It is in agreement with the work done by Padem et al. (1997). The highest fruit yield with 48.76 t/ha (Figure 1), number of fruits per square meter with 22.68 fruits, number of branches per plant with 3.03 branches, plant height with 140.9 cm, fruit length with 33.18 cm and fruit width with 5.66 cm was obtained by use of 50 mg/L foliar spraying of humic acid (H_3). H_2 treatment (25 mg/L foliar spraying of humic acid) with 2.90 braches per plant statistically was placed in same level with H_3 treatment. On the other hand, the lowest fruit yield, number of fruit per square meter, number of branches per plant, plant height, fruit length and fruit width was recorded from H_1 treatment (without humic acid spraying) respectively with 30.3 t/ha (Figure 1), 17.18 fruits, 2.50 branches, 94.14 cm, 19.55 cm and 3.75 cm. Similar results were reported by Nardi et al. (2002), Arancon et al. (2006) and Obsuwan et al. (2011).

Effect of nitrogen fertilizer management

Results of variance analysis show that, the effect of nitrogen fertilizer management on fruit yield, number of fruit per square meter, plant height, fruit length and fruit width at 1% and on number of branches per plant at 5% was significant. Results showed that nitrogen application up to 80 kg/ha significantly increases fruit yield and other studied attributes. Pal et al. (2002) with study Effect of nitrogen and phosphorus levels on growth and yield of Eggplant hybrid similar results were reported. The maximum fruit yield with 51.38 t/ha (Figure 2), number of fruits per square meter with 22.59 fruits, number of branches per plant with 3.04 branches, plant height with 130 cm, fruit length with 30.43 cm and fruit width with 5.77 cm was obtained from N_3 (80 kg/ha nitrogen fertilizer) treatment (Table 3). The minimum amount of fruit yield with 23.13 t/ha, number of fruit per square meter with 17.11 fruits, number of branches per plant with 2.57 branches, plant height with 101.3 cm, fruit length with 19.73 cm and fruit width with 3.81 cm was recorded from N_1 (no nitrogen fertilizer) treatment. The N_4 (roots inoculation with nitroxin) treatment with 17.86 fruits per square meter and 4.10 cm fruit width statistically was placed at same level with N_1 treatment. Similar results were reported by Sat and Saimbhi (2003), Akanbi et al.

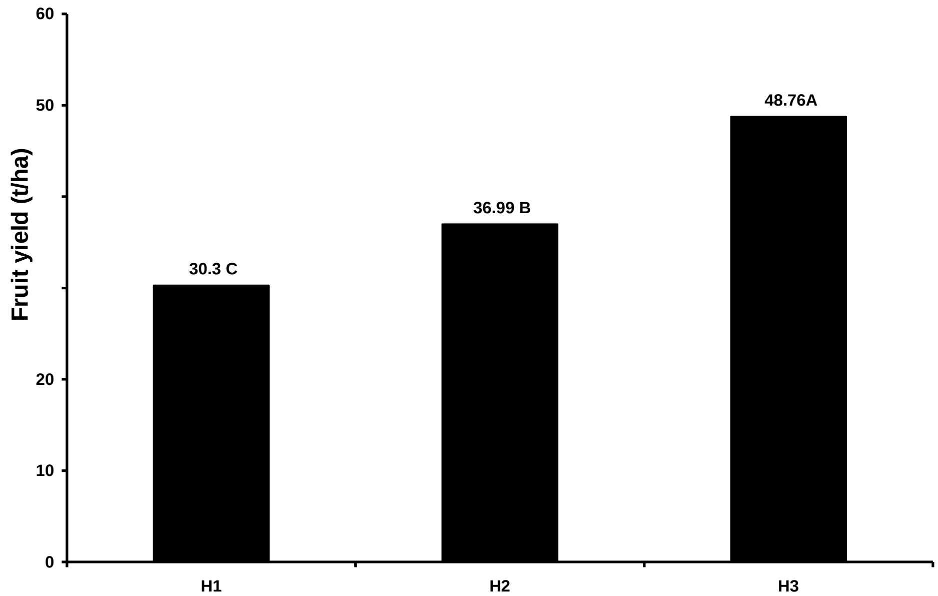

Figure 1. Effect of humic acid foliar spraying on fruit yield.

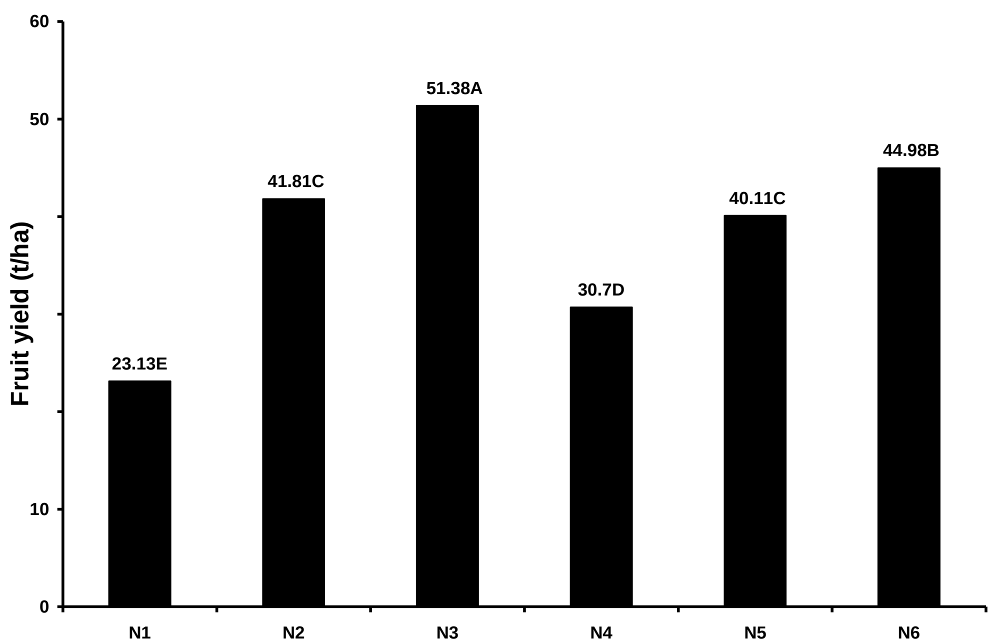

Figure 2. Effect of nitrogen fertilizer management on fruit yield.

(2007) and Aujla et al. (2007).

Interaction effect of humic acid and nitrogen

With attention to results of variance analysis (Table 2), the interaction effect of foliar humic acid spraying and nitrogen fertilizer management on fruit yield at 1% and on number of fruit per square meter, plant height, fruit length and fruit width at 5% was significant. Also, interaction effect does not showed significant differences on number of branches per plant. Comparison of mean between humic acid spraying treatments showed that (Table 4), the highest fruit yield with 66.99 t/ha (Figure 3), number of fruit per square meter with 26.20 fruits, plant height with 145.4 cm, fruit length with 36.97 cm and fruit width with 6.56 cm was recorded from H_3N_3 treatment (50 mg/L foliar spraying of humic acid and 80 kg/ha nitrogen fertilizer).

Table 4. Comparison of mean between interaction effects of humic acid spraying and nitrogen fertilizer management.

Treatments	No. of fruit (m^2)	No. of branches per plant	Plant height (cm)	Fruit length (cm)	Fruit width (cm)
H_1N_1	15.33^{j}	2^{a}	56.60^{g}	14.60^{h}	3.36^{gh}
H_1N_2	$16.87^{hi}j$	2.3^{a}	111.1^{cdef}	18.70^{fg}	$3.60f^{gh}$
H_1N_3	20.60^{cd}	3^{a}	105.6^{def}	26.07^{cd}	4.50^{de}
H_1N_4	16.10^{ij}	2.3^{a}	92.60^{f}	16.57^{gh}	2.96^{h}
H_1N_5	16.70^{ij}	2.6^{a}	96.40^{f}	18.13^{g}	3.76^{efg}
H_1N_6	17.47^{fghi}	2.6^{a}	102.5^{ef}	23.23^{de}	4.30^{def}
H_2N_1	17.07^{ghij}	2.7^{a}	121.1^{bcde}	$19.03f^{g}$	3.80^{efg}
H_2N_2	19.27^{cdef}	3^{a}	123.5^{abcde}	27.30^{c}	4.66^{cd}
H_2N_3	20.97^{c}	3^{a}	139^{ab}	28.27^{bc}	6.26^{a}
H_2N_4	17.77^{efghi}	2.8^{a}	111.5^{cdef}	21.43^{ef}	4.46^{de}
H_2N_5	18.77^{defgh}	2.8^{a}	131.2^{abc}	25.57^{cd}	4.33^{def}
H_2N_6	20.50^{cd}	3^{a}	134.7^{ab}	27.27^{c}	5.30^{bc}
H_3N_1	18.93^{cdefg}	3^{a}	126.2^{abcd}	25.57^{cd}	4.26^{def}
H_3N_2	23.67^{b}	3^{a}	145.4^{a}	35.60^{a}	6.06^{a}
H_3N_3	26.20^{a}	3.1^{a}	145.4^{a}	36.97^{a}	6.56^{a}
H_3N_4	19.70^{cde}	3^{a}	141.5^{ab}	30.43^{b}	4.86^{cd}
H_3N_5	22.93^{b}	3^{a}	142.2^{ab}	35^{a}	5.90^{ab}
H_3N_6	24.63^{ab}	3^{a}	144.8^{a}	35.50^{a}	6.30^{a}

Within each column, means followed by the same letter do not differ significantly at P<0.05.

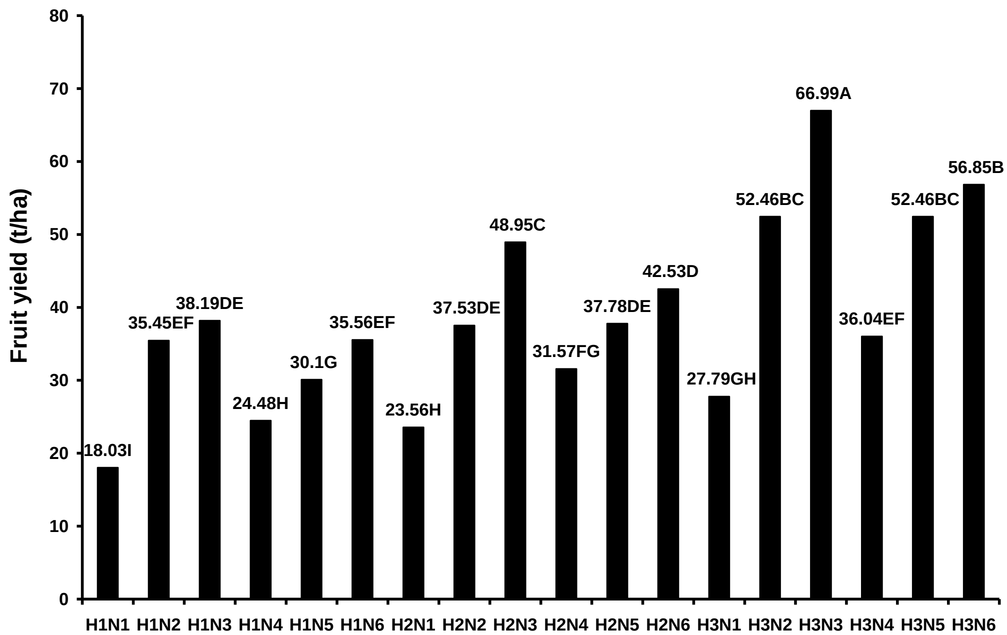

Figure 3. Interaction effect of humic acid foliar spraying and nitrogen fertilizer management on fruit yield.

On the other hand, the lowest fruit yield with 18.03 t/ha, number of fruit per square meter with 15.33 fruits, plant height with 56.60 cm and fruit length with 14.60 cm was recorded from H_1N_1 treatment (without humic acid spraying and no nitrogen fertilizer). Also, the minimum amount of fruit width was obtained from H_1N_4 (without humic acid spraying and roots inoculation with nitroxin) treatment with 2.96 cm. Similar results were reported by Dursun et al. (1999), Pal et al. (2002), Sat and Saimbhi (2003), Arancon et al. (2003) and Arancon et al. (2006).

Conclusion

As a whole, results of the present study showed that foliar spraying of humic acid had significant effect on all measured traits and increase concentration of humic acid foliar spraying up to 50 mg/L lead to improved plant growth and yield of eggplant. On the other hand, there were significant differences between nitrogen levels on all cases of variables. All traits were improved with nitrogen fertilization. The highest amounts of all measured traits were obtained by 80 kg/ha pure nitrogen application (N_3). Under our experiment conditions, this plant showed a good response to the integration of biological and chemical nitrogen fertilization. The results clearly demonstrate that integration of biological nitrogen fertilizer (Nitroxin) along with chemical nitrogen fertilizer in N_6 level (40 kg/ha pure nitrogen + roots inoculation with nitroxin) in all traits after N_3 treatment was Superior. Thus, our study shows that application of 50 mg/L humic acid foliar spraying and 80 kg/ha nitrogen fertilizers are recommended for eggplant production.

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