Performance of Eggplant (*Solanum melongena* L.) and Sweet Pepper (*Capsicum annuum* L.) in Intercropping System under Different Rates of Nitrogen

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Korean Society for Horticultural Science

Vol. 51, No. 5 October 31, 2010

Hort. Environ. Biotechnol. 51(5):367-372. 2010.

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Abstract. The objective of this study was to determine the effect of nitrogen fertilizer levels on the performance of an eggplant (*Solanum melongena* L.) and sweet pepper (*Capsicum annuum* L) intercropping system in open field at four different levels (0, 50, 100 and 150 Kg/ha). Plant height, lateral stem length, leaf chlorophyll content, days to 1st flowering, flower number, fruit weight and plant yield were assessed. Results of this study indicated that nitrogen fertilizer increased some growth characteristics (plant height, lateral stem number, and leaf chlorophyll) of eggplant and pepper in intercropping system. Nitrogen fertilizer affected eggplant flowering factors (flower number and days to 1st flowering). Days to 1st flowering decreased by nitrogen treatments and treated plants flowered earlier than control. It was observed that fertilization with 50 Kg N ha^{-1} resulted in the best fruit weight and plant yield for both eggplant and pepper in intercropping system.

Additional key words: flower number, fruit weight, leaf chlorophyll, plant height, yield

Introduction

It is becoming more important to the raise crop productivity in order to meet the increasing food requirements of an increasing global population. Moreover, crop production per unit area must be increased because of the remaining fixed or diminishing suitable land for food production (Ertan and Ismail, 2005). Modern industrialized agriculture, which typically uses monocultures, has increased yields enormously in the developed countries, but this improvement has not been without its costs. The production and operation of machines and the synthesis of fertilizers and pesticides require an enormous amount of energy. Other costs can be high as well, ranging from degradation and disruption of the environment to human pesticide poisonings (Karlidag and Ertan, 2009). Intercropping is becoming increasingly important to boost crop productivity to meet food demands of an increasing worldwide population. Intercropping can offer many advantages, such as more efficient use of resources(water, nutrients and solar energy), economic savings and insurance against crop failure as well as environmental advantages by reducing the accumulation of NO_3^- -N in the soil profile, and reducing N inputs (Wenxue et al., 2003).

The yield depends upon certain production factors. Among these factors, balanced nutrition plays a significant role. Nitrogen is a major constituent of several of the most important substances which occur in plants. The essential elements in the nitrogen compounds comprise from 40 to 50% of the dry matter of the protoplasm, the living substance of plant cells (Togun et al., 2003). For this reason, nitrogen is required in relatively large quantities for growth processes in plants. Nitrogen is known to promote production, partitioning and accumulation of dry matter in crop plant (Akanbi et al., 2007). It is a well known that adequate nitrogen is required by pepper for satisfactory growth, development and high yield. Thus, an adequate level of nitrogen is very vital to increase the production and yield of pepper and eggplant. Hence, the present investigation was undertaken to elucidate the suitable nitrogen fertilizer level for an egg shaped eggplant and sweet pepper in mix system for higher productivity and sustainability.

Materials and Methods

Plant Preparation

The investigation was conducted during the 2006 growing season at the experimental field of the Agricultural Faculty, University of Birjand (latitude 32°53 N′, longitude 59°13′ E and 1470 m elevation), Iran. This site represents the range of dry conditions. Annual rainfall ranges is between 91 and 120 mm and mean annual relative humidity is 37%. Soil sample (0-30 cm depth) was taken with auger after the site had been prepared for cultivation. The sample was analyzed for physical and chemical properties using standard laboratory procedures described by Mylavapus and Kennelley (2002) and data is shown in Table 1. The experimental field was cleared, ploughed, harrowed and divided into plots. Potassium (K_2O_5) and phosphorus (P_2O_5) were applied 50 and 100 kg ha^{-1}, respectively, each at the time of soil preparation. Seeds of eggplant and pepper were established in a greenhouse in large trays with a 1:1 mixture of sand and peat (1:1 v/v) separately. Irrigation was done after sowing whenever necessary. After several weeks seven seedlings of eggplants and pepper were hand-transplanted into well-prepared beds in the field. Each pepper was planted in the middle of eggplant plants. The spacing

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Received April 22, 2010; accepted June 17, 2010.

Table 1. Soil characteristics of experimental field.

Soil factors	
N (%)	0.05
P (ppm)	14
K (ppm)	270
pH	7.1
Clay (%)	19
Silt (%)	41
Sand (%)	40

between rows was 0.5 m and spacing between plants (eggplant and pepper) was 0.5 m. Plots were irrigated when necessary during the growing season. All practical managements were included; mulching, weeding and other horticultural operations were done traditionally.

Treatments

Treatments consisted of four levels of nitrogen (0, 50, 100 and 150 Kg / ha). The source for nitrogen fertilizer was urea that was split into three equal parts and applied at ten days after transplanting (DAP) as basal; the remaining portions were used as top dressing at 30 and 50 DAP.

Measurements

Ten plants in each replication were used to assess plant height, leaf number, number and length of lateral stem and internodes length at three growing stages including vegetative, flowering and reproductive. Leaf chlorophyll content was measured by a portable chlorophyll meter, SPAD-502 (Minolta Corporation, Ramsey, NJ). Leaves samples were oven dried at 75° C for 72 h; leaf dry weight for each plant was weighed using digital balance and recorded in gram (Basela and Mahadeen, 2008). Days to the first flowering were estimated for each plot and number of flowers per plant was evaluated based on the method by Remison (1997). Mature fruits were harvested at 10-14 day intervals to assess the average fruit weight (g) and fruit yield per plant (g/plant).

Experimental design and statistical analysis

The experiment was arranged in a completely randomized block design (CRBD) with four treatments and three replications, each replication with ten plants. Data were analyzed using MSTAT-C and means were compared by Duncan's multiple range test (DMRT) at 5% level of confidence.

Results and Discussion

Data (Tables 2-7) showed that nitrogen fertilization significantly affects eggplant and pepper growth, yield and fruit quality.

Vegetative growth

Plant height, number and length of lateral stems

Eggplant: Nitrogen fertilizer application increased plant height at all stages including vegetative, flowering and reproductive (Table 2). The level of 100 kg N ha^{-1} produced the tallest plants and the shortest plants formed in the control (at vegetative stages). However, no significant difference was found between three treatments: 50, 100 and 150 kg N ha^{-1} (at all stages). The obtained results were in agreement with Bar et al. (2001) and Boroujerdnia and Alemzadeh (2007). The effects of nitrogen fertilizer on the stem characteristics of eggplant were significant (Table 2). The highest lateral stem length (24.67 cm) and lateral stem number (14.67) were obtained at 100 and 50 kg N ha^{-1}, respectively (at flowering stage), while the least related to control treatment (19 cm and 11). Similar result was observed in the study done by Bar et al. (2001).

Pepper: Results indicated the lowest plant height by control plants at all stages (Table 3). However, no significant difference was found between three treatments: 50, 100 and 150 kg N ha-1(at vegetative and reproductive stages). Our results were in agreement with Bowen and Frey (2002) and Ge et al. (2008). Stem characteristics of pepper were affected by nitrogen fertilizer (Table 3). The highest lateral stems length (20 cm) and number of lateral stems (16.33) were obtained at 100 kg N ha-1 (at flowering stage), while the least related to

Table 2. Effect of nitrogen fertilizer on vegetative characteristics of eggplant.

Treatment	Plant height (cm)			Lateral stem length (cm)	Lateral stem number	
	Veg[z].	Flower[y].	Rep[x].	Flower.	Veg.	Flower.
0 (control)	8.67b	20.33b	28.67b	19.00b	8.66b	11.00b
50 kgN ha^{-1}	11.00a	28.00a	34.33a	23.00a	11.00ab	14.67a
100 kgN ha^{-1}	12.00a	27.33a	38.33a	24.67a	11.33ab	13.67a
150 kgN ha^{-1}	11.67a	28.33a	36.33a	24.00a	12.00a	14.33a

[z]Vegetative stage.
[y]Flowering stage.
[x]Reproductive stage.
Within each column, same letter indicates no significant difference between treatments at 5% levels

control treatment (15.67 cm, 11.67). Height of plant can be considered as one of the indices of plant vigour ordinarily and it depends upon vigour and growth habit of the plant. Soil nutrients are also very important for the height of plants. Higher dose of nitrogen increased plant height (Pervez et al., 2004).

Leaf number

Eggplant: By increasing the nitrogen fertilizer rate the leaf number increased (Table 4). The highest leaf number was related to the fourth treatment (150 kg N ha^{-1}) with 9 leaves (at vegetative stage) and 54.33 leaves (at reproductive stage), while the lowest was related to the control treatment with 5 leaves (at vegetative stage) and 45 leaves (at reproductive stage). The obtained result was in agreement with Ayodele (2002).

Pepper: Leaf number was affected by nitrogen fertilizer at all stages (Table 5). The highest leaf number was observed in 100 kg N ha^{-1} at all stages (10.33, 41.67 and 71 leaves), while the least leaf number was recorded at control (6, 28 and 51.67 leaves) which was in agreement with findings of Boroujerdnia and Alemzadeh (2007). Each increase in inorganic fertilizer dose tended to increase number of leaves per plant compared with control. This variation might be due to the availability of nutrients especially nitrogen and could be due to the improvement of soil water holding capacity as mentioned earlier by Roe and Cornforth (2000).

Table 3. Effect of nitrogen fertilizer on vegetative characteristics of pepper.

Treatment	Plant height (cm)			Lateral stem length (cm)	Lateral stem number	
	Veg[z].	Flower[y].	Rep[x].	Flower.	Veg.	Flower.
0 (control)	8.67b	20.33b	28.67b	19.00b	8.66b	11.00b
50 kgN ha^{-1}	11.00a	28.00a	34.33a	23.00a	11.00ab	14.67a
100 kgN ha^{-1}	12.00a	27.33a	38.33a	24.67a	11.33ab	13.67a
150 kgN ha^{-1}	11.67a	28.33a	36.33a	24.00a	12.00a	14.33a

[z]Vegetative stage.
[y]Flowering stage.
[x]Reproductive stage.
Within each column, same letter indicates no significant difference between treatments at 5% level.

Table 4. Effect of nitrogen fertilizer on vegetative characteristics of eggplant.

Treatment	Leaf number			Leaf chlorophyll			Leaf dry matter content (%)
	Veg[z].	Flower[y].	Rep[x].	Veg.	Flower.	Rep.	Rep.
0 (control)	5.00b	26.67c	45.00b	42.67b	48.00b	55.00b	16.33d
50 kgN ha^{-1}	7.00b	34.00b	53.67a	46.33ab	52.00ab	66.00a	17.33c
100 kgN ha^{-1}	7.33a	40.00a	54.00a	48.00a	55.00a	62.67a	18.33b
150 kgN ha^{-1}	9.00a	38.00ab	54.33a	49.00a	55.67a	62.33a	19.00a

[z]Vegetative stage.
[y]Flowering stage.
[x]Reproductive stage.
Within each column, same letter indicates no significant difference between treatments at 5% levels.

Table 5. Effect of nitrogen fertilizer on vegetative characteristics of pepper.

Treatment	Leaf number			Leaf chlorophyll			Leaf dry matter content (%)
	Veg[z].	Flower[y].	Rep[x].	Veg.	Flower.	Rep.	Rep.
0 (control)	6.00b	28.00b	51.67c	42.67b	50.33b	58.33b	17.33b
50 kgN ha^{-1}	10.00a	37.33a	63.67b	49.67a	59.00a	64.33a	20.00a
100 kgN ha^{-1}	10.33a	41.67a	71.00a	50.67a	59.33a	67.67a	21.00a
150 kgN ha^{-1}	9.00a	40.33a	67.68ab	53.67a	59.67a	66.33a	20.00a

[z]Vegetative stage.
[y]Flowering stage.
[x]Reproductive stage.
Within each column, same letter indicates no significant difference between treatments at 5% levels.

Leaf chlorophyll content

Eggplant: Results indicated the lowest leaf chlorophyll content by control plants at all stages (Table 4). However, no significant difference was found between three treatments: 50, 100 and 150 kg N ha^{-1}(at all stages). Similar results have been reported in investigations conducted by Bowen and Frey (2002) and Basela et al. (2008).

Pepper: The effect of nitrogen fertilizer level on leaf chlorophyll content was significant at all stages (Table 5). The highest leaf chlorophyll content was related to the fourth treatment (150 kg N ha^{-1}) at vegetative and flowering stages (53.67 and 59.67) while the lowest was related to the control treatment (42.67 and 50.33). However, no significant difference was found between the three treatments: 50, 100 and 150 kg N ha^{-1}(at all stages), which were in agreement with results obtained by Aroiee and Omidbaigi (2004) and Ge et al. (2008). A promotion effect of inorganic fertilizers on chlorophyll contents might be attributed to the fact that N is a constituent of chlorophyll molecule. Moreover, nitrogen is the main constituent of all amino acids in proteins and lipids that act as a structural compound of the chloroplast (Basela and Mahadeen, 2008).

Leaf dry matter content

Eggplant: Nitrogen fertilizer level significantly affected the leaf dry matter content at flowering stage (Table 4). The highest leaf dry matter content was observed in 150 kg N ha^{-1} (19 %), while the least leaf dry matter content was recorded at control (16.33%). Similarly, Magdatena (2003) reported that leaf dry matter content increased as N rate increased.

Pepper: By increasing the nitrogen fertilizer rate the leaf dry matter content increased, but the difference between 50, 100 and 150 kg N ha^{-1} treatments was not statistically significant. (Table 5). The highest leaf dry matter content was obtained at 100 kg N ha^{-1} application(21%), while the least leaf dry matter content was obtained in the control (17.33%.). Takebe et al. (1995) reported that increments in leaf dry weight may be due to a combination of nitrogen with plant matter produced during photosynthesis such as glucose, ascorbic acid, amino acids and protein. Also, Tei et al. (2000) reported that increasing the rate of nitrogen fertilizer significantly increased the dry weight of leaves lettuce.

Reproductive growth

Days to 1st flowering and node number to first flower

Eggplant: Nitrogen fertilizer level significantly affected the node number to first flower and days to 1st flowering were significant (Table 6). The highest and lowest node number to first flower was obtained at 100 kg N ha^{-1} with 11 nodes and control with 7.66 nodes, respectively. Days to 1st flowering ranged from 43 days to 49.33 days. Nitrogen deficiency retarded the vegetative as well as reproductive growth, which resulted in more days to flowering and fruit setting. Similarly, more nitrogen gave maximum days to flowering and fruit setting. Nitrogen enhanced vegetative growth and reduced reproductive growth (Jilani et al., 2008); therefore, a fertilizer dose of 100 kg N ha-1 proved better for minimum days to flowering, which leads to early fruit setting.

Pepper: Days to the first flowering ranged from 45 days to 49.67 days (Table 7). Thus nitrogen treatments decreased the days to the first flowering and treated plants flowered earlier than control (Table 7), in agreement with findings of Satpal and Saimbhi (2003) and Law and Egharevba (2009). The effect of nitrogen fertilizer level on node number to the first

Table 6. Effect of nitrogen fertilizer on reproductive characteristics of eggplant.

Treatments	Node number to first Flower	Days to 1st flowering	Flower number at lateral stem	Fruit number at lateral stem	Fruit weight (g)	Yield plant (g)
0 (control)	7.66c	49.33a	4.00b	1.66b	307b	3165b
50 kgN ha^{-1}	10.00ab	44.00c	6.00a	2.66ab	385a	4053a
100 kgN ha^{-1}	11.00a	43.00c	6.33a	3.00a	371a	4083a
150 kgN ha^{-1}	9.66b	46.33b	5.33a	2.33ab	361a	3743ab

Within each column, same letter indicates no significant difference between treatments at 5% levels.

Table 7. Effect of nitrogen fertilizer on reproductive characteristics of pepper.

Treatments	Node number to first Flower	Days to 1st flowering	Flower number at lateral stem	Fruit number at lateral stem	Fruit weight (g)	Yield plant (g)
0 (control)	9.66a	49.67a	5.00ab	1.66b	63.33b	1401c
50 kgN ha^{-1}	11.33a	45.00b	6.00a	2.66a	85.00a	1825a
100 kgN ha^{-1}	12.33a	45.33ab	5.66ab	2.66a	85.00a	1748ab
150 kgN ha^{-1}	11.00ab	45.00b	4.66b	2.00ab	71.67ab	1511bc

Within each column, same letter indicates no significant difference between treatments at 5% levels.

flower was not significant (Data not shown).

Flower and fruit number at lateral stems

Eggplant: The effects of nitrogen fertilizer level on flower and fruit number at lateral stems were significant (Table 6). The level of 100 kg N ha^{-1} fertilizer produced the most flower and fruit number at lateral stem with 6.33 flowers and 3 fruits, while the least of these variables were related to control treatment with 4 flowers and 1.66 fruits. This result agrees with the findings by Solvadore et al. (1997), Xu et al. (2001) and Olaniyi (2008).

Pepper: Flower and fruit number at lateral stems increased with application nitrogen fertilizer (Table 7). The highest flower and fruit number at lateral stems were observed in 50 Kg N ha^{-1} (6 flowers and 2.66 fruits), while the least flower and fruit number were recorded at 150 Kg N ha^{-1} and control (4.66 flowers and 1.66 fruits). Ali and Kelly (1992) suggested that the maintenance of vigorous vegetative growth from flower bud formation throughout fruit development might ensure sufficient assimilate supply to alleviate stress on growing processes in the developing buds. Increase of soil fertility delayed the commencement of flowering and fruit set of sweet pepper (Shrivastava, 1996).

Fruit weight

Eggplant: This experiment revealed that statistical significances differences existed among the treatments for average fruit weight (Table 6). Data showed the highest fruit weight (385 g) was observed from 50 Kg N ha^{-1} treatment, while the lowest were related to the control (307 g). However, no significant difference was found between three treatments: 50, 100 and 150 kg N ha^{-1}. Similar results have been reported in investigations conducted by Bar et al. (2001) and Akanbi et al. (2007).

Pepper: By increasing the nitrogen fertilizer rate fruit weight increased (Table 7). The level of 100 kg nitrogen fertilizer produced the highest fruit weight (85.0 g), while control treatment produced the lowest fruit weight (63.33 g). These results are consistent with those reported by Magdatena (2003) and Aujla et al. (2007) who also reported that increasing the rate of nitrogen fertilizers increased the average fruit weight and fruit volume.

Plant Yield

Eggplant: The effect of nitrogen fertilizer level on eggplant yield was significant (Table 6). The highest yield in plant was obtained as 4083(g) after application of 100 kg ha^{-1}; the lowest yield was obtained as 3165(g) in the zero nitrogen application, i.e. the control, in agreement with Tei et al. (2000), Tumbare et al. (2004) and Fernandez-Luqueno et al. (2010) who reported that increments in the nitrogen rate of the fertilizers increased the number of fruits. Increasing the N levels of the fertilizers to 50 kg N ha^{-1} significantly increased the yield of eggplant, while yield decreased at the highest nitrogen dose. This decrease in yield might be due to toxicity in the plant (Tabatabaie and Malakouti, 1997).

Pepper: The result indicated that the yield (plant $^{-1}$) was affected by nitrogen fertilizer (Table 7). Data showed the highest yield per plant (1825 g) was observed from 50 Kg N treatment, while the lowest were related to the control (1401 g). Increasing the N levels of the fertilizers to 50 kg N ha^{-1} significantly increased the yield of pepper, while yield decreased at the highest nitrogen dose. This decrease in yield might be due to toxicity in the plant (Tabatabaies and Malakouti, 1997). The marked effect of nitrogen on yield might be due to the cumulative stimulating effect of nitrogen on the vegetative growth characters which form the base for flowering and fruiting.

Acknowledgement: The research was funded by Ferdowsi University of Mashhad (Islamic Republic of Iran).

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