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Yield and Yield Components of Potato (*Solanum Tuberosum* L.) Tuber as Affected by Nitrogen Fertilizer and Plant Density

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Abestract: In order to investigate the effects of plant density and nitrogen fertilizer level on yield and yield components of potato crop (Agria cultivar), a field experiment was carried out in Ardabil, Iran, in 2006. the experiment was factorial in the base of randomized complete block design with three replications. Factors included nitrogen fertilizer level (0, 80, 160 and 200 kg ha^{-1} as urea) and plant density (5.5, 7.5 and 11 plant m^{-2}). Results showed that increasing nitrogen level up to 80 kg ha^{-1} led to more tuber yield. The highest yield, number of stolon, harvest index, number of tuber and dry weight of tuber were obtained with application of jointly 80 and160 kg ha^{-1} nitrogen. Increasing plant density resulted in higher tuber yield, number of stolon, dry weight of tuber and total dry matter yield and decreased harvest index. Increasing nitrogen fertilizer rate up to 160 kg ha^{-1} increased mean tuber weight and total dry matter yield. To obtain the highest yield and avoid of environmental pollutions, use of 80 kg ha^{-1} nitrogen fertilizer with density of 11 plant m^{-2} is recommended.

Key words: Nitrogen, Plant density, Potato, Yield components and Yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is grown and eaten in majority of countries more than any other crops, and in the global economy, it is the fourth most important crop after the three cereals including maize, rice and wheat (Stepjhen, 1999). Plant density in potato affects some of important plant traits such as total yield, tuber size distribution and tuber quality. So it might be argued that increase in plant density leads to decrease in mean tuber weight and an increase in number of tuber and yield per unit area (Osaki *et al.,* 1995). Increase in plant density decreases mean tuber size probably because of plant nutrient elements reduction, increase in interspecies competition and large number of tubers produced by high numbers of stems (Khajaehpour, 2006).

Marguerite, *et al.* (2006) showed that the mean maximum increase in total tuber yield, generated by nitrogen fertilizer against the zero-N treatment, was 34.3% and ranged from 10.5% to 54.7%, and in regard to potato, the improvement of N efficiency should be also achieved by splitting N fertilizer applications and by monitoring the crop N needs to match crop N requirements and mineral N supply throughout the growing season. Georgakis *et al*. (1997) concluded that by increasing plant density, the tuber yield was increased. Karafyllidis *et al*. (1997) reported that plant density strongly affected yield, both by number and by weight, and more tubers and yield per square meter were expected in higher plant densities. Alvin *et al*. (2007) reported that with increasing plant density, yield of potato increased. On the other hand, increase in plant density, probably is the reason of the lack of nutrient elements for each plant or production of more tubers per unit area and reduction of their mean size. In several studies, narrow in-row spacing appeared to increase yield (Jamaati-e-Somarin *et al*., 2009).

The aim of this study was to evaluate the effect of different nitrogen levels and plant densities on yield and yield components of potato tuber in order to determine the most suitable density and nitrogen level to achieve the highest yields.

MATERIALS AND METHODS

In order to investigate the plant density and nitrogen fertilizer on yield and yield components of potato tuber cv. Agria, a factorial experiment based on randomized complete block design with three replications was conducted at the research field of University of Mohaghegh Ardabili, Ardabil, Iran, in 2006. The first factor was nitrogen level (0, 80, 160 and 200 kg ha^{-1}) and the second was plant density (5.5, 7.5 and 11 plant m^{-2}).

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Nitrogen was given as urea form at 2 stages (namely, planting date and date of earthing up). According to soil analysis results, total nitrogen content was 0.56% and soil texture was sandy-loam. Rows were spaced 60 cm to each other and plots contained 6 rows each 3 meters. In order to prevent nitrogen effects in adjacent plots (border effects), 1.5 m borders were made. Tubers of 60-70 grams were sown on 13 May 2006. Sowing depth was 12-13 cm. The last harvest was assigned for the yield. To promote storage capability, ten days before harvest, aerial parts were removed (Khajehpour, 2006). Sampling was done from 2 m^2 plot area, and then tubers were transferred to the laboratory. Before any measurements, tubers were washed along with roots and stolons. Different plant tissues were dried separately for 48 hours at 75°C and weighed. Amount of harvest index was calculated as follows:

Harvest index = (Economical yield/Biological yield) ´ 100

Also, total dry matter yield was calculated from sum of dry matter of aerial and sub-ground parts. Results were analyzed by SAS software and mean comparisons were done via Duncan's multiple range tests.

RESULTS AND DISCUSSION

Number of Stolon and Tuber:

Using 80 and 160 kg ha^{-1} nitrogen, the number of stolon m^{-2} significantly was more than control and 200 kg ha^{-1}. This value was the highest at 160 kg $ha^{-1}$of about 96.83. This trend is obvious for the number of tuber m^{-2} so that, the rate of 160 kg ha^{-1} caused the number of 100.9 tubers m^{-2} (Table 1). In contrast, the highest plant density caused the highest number of stolon and other two levels were placed afterwards. The impact of the first and the third densities showed that the third one produced approximately two times more stolons than the first (112.42 stolons m^{-2}). Same to this, plant density has been increased. Of course, it was expected that increase in plant density and decrease in the inter plant distances would lead to decrease in the number of stolons but, because of increase in applied nitrogen amounts, this appears to be rational. As it is obvious in the results section, this trait follows the same trend in two other densities. With regard to the fact that produced tubers per plant are the functions of the number of stolons so, it is expectable that in higher densities, the number of produced tubers be more, as well. This is, with partial difference, similar to the increment of the number of stolons. In fact, these traits tend to increase with increasing applied nitrogen value and density, separately. Furthermore, the interaction effect of nitrogen fertilizer × plant density, had significant impact on them so that, density of 11 plant m^{-2} along with the application of 80 kg ha^{-1} nitrogen and also, 160 kg ha^{-1} nitrogen with the mentioned density, caused the highest number of stolons of 121.55 and 125.03, respectively (Table 2). According to the results, in both treatments, the highest density along with the nitrogen levels of the 80 and 160 kg ha^{-1} increased this trait as they increased the number of stolons. In other words, high nitrogen levels could overcome the inter plant competitions caused by the high densities limiting the environmental resources for plants. Range of these changes in the number of tuber per unit area was higher than the number of stolons so that, interaction effect of all plant densities × nitrogen fertilizers could show the significant differences. However, values of mentioned treatments which caused the highest number of stolons, made the highest number of tubers per unit area, as well.

Tuber Yield and Dry Weight:

The effect of plant density and nitrogen level was significant (**P<0.01) on tuber yield. Results showed that increase in nitrogen rates up to favorable point led to increase in tuber yield per unit area. The highest value of this trait affected by nitrogen was obtained at 80 and 160 kg h^{-1} and the lowest one belonged to control. With increasing nitrogen application, the number of stolons including tuber, number of tubers and consequently yield, were increased. Also, increase in density led to significant increase in tuber yield so that, the most and the least tuber yield was obtained at 11 plant m^{-2} and at 5.5 and 7.5 plant m^{-2}, respectively (Table1).

The effect of plant density and nitrogen level on tuber dry weight was significant (**P<0.01). Based on the results, tuber dry weight was increased up to favorable amounts of applied nitrogen per unit area. Also, it was observed that increase in density caused significant increase in tuber dry weight. The highest and the lowest tuber dry weight was gained at 11 plant m^{-2}, and jointly at 5.5 and 7.5 plant m^{-2}, respectively (Table1).

Mean Tuber Weight and Total Plant Dry Matter:

The effect of nitrogen and plant density (**P<0.01) was significant on mean tuber weight. With increasing nitrogen up to definite point, this trait was increased so that, the highest value was obtained with application of 160 kg ha^{-1} nitrogen. Meanwhile, control and 200 kg ha^{-1} rates had significant effect on mean tuber weight.

Also, it was seen that the lowest mean tuber weight was achieved at 7.5 and 11 plant m^{-2} and the highest one was achieved at 5.5 plant m^{-2} (Table 1).

Total plant dry matter was affected by plant density and nitrogen, significantly (**P<0.01). Results (Table 1) showed that application of nitrogen up to 160 kg ha^{-1} resulted in increase in this trait and excess rates caused decrease. Plant density had very positive effect. As it was seen in majority of traits, increase in nitrogen up to a distinct rate led to increase in total plant dry matter yield and afterwards, decreased.

Harvest index:

Plant density and nitrogen level had significant effect (**P<0.01) on harvest index. With increasing plant density and nitrogen level, harvest index was decreased so that, density of 5.5 plant m^{-2} caused the highest and densities of 7.5 and 11 plant m^{-2} jointly, caused the lowest harvest index. Also, nitrogen levels of 80 and 160 kg ha^{-1} made the highest and control and 200 kg ha^{-1} caused the lowest harvest index (Table 1). As we see, second and third levels of nitrogen application approximately in all traits, have made the highest amounts of traits but this increase frequently have made by the third level of plant density. According to Table 2, interactions affect 160 kg ha^{-1} × 5.5 plant m^{-2} led to the highest value of this trait.

Table 1: Effects of plant density and nitrogen level on measured traits.

Treatments		Number of stolon m^2	Number of tuber m^2	Mean tuber weight (gr)	Total plant dry matter (kg m^{-2})	tuber (gr m^{-2}) Dry weight of	Tuber yield (gr m^{-2})	Harvest index (%)
Nitrogen	0	72.52c	63.86b	23.29b	0.9c	498.79b	2024.6b	68.79b
fertilizer	80	94.56a	93.35a	30.21ab	1.17b	669.95a	2994.1a	70.83a
values	160	96.83a	100.9a	33.67a	1.29a	728.18a	3174.6a	72.51a
(kg ha^{-1})	200	86.98b	80.23ab	24.85b	1.12b	498.23b	2457.0b	67.49b
Plant	5.5	66.94c	77.12b	30.55a	0.91c	525.35b	2346.3b	72.24a
densities	7.5	83.81b	81.62ab	27.36ab	1.05b	580.32b	2473.8b	69.07b
(plant m^{-2})	11	112.42a	95.0a	26.11ab	1.4a	742.45a	3116.6a	68.4b

Numbers with the same letters in each column, have no significant differences to each other.

Table 2: Interaction effects of plant density and nitrogen level on measured traits.

Interaction effects	Number of stolon m^2	Number of tuber m^2	Mean tuber weight (gr)	Total plant dry matter (kg m^{-2})	Dry weight of tuber (gr m^{-2})	Tuber yield (gr m^{-2})	Harvest index (%)
Control × 5.5 plant m^{-2}	57.1 h	58.18 b	34.12 ab	0.67 f	371.48 f	1650.00e	71.04 abc
Control × 7.5 plant m^{-2}	67.87 fg	75.12 ab	27.95 b	0.84 e	445.27 f	1651.7e	67.42 bc
Control × 11 plant m^{-2}	92.58 c	58.28 b	23.4 b	1.2 c	679.62 abcd	2772.1abcd	65.64 c
80 kg ha^{-1} × 5.5 plant m^{-2}	71.77 ef	86.71 ab	38.00 ab	0.97 de	649.25 bcd	3191.6abc	74.18 ab
80 kg ha^{-1} × 7.5 plant m^{-2}	90.37 c	80.21 ab	31.17 b	0.99 d	582.47 de	2478.7bcde	70.87 abc
80 kg ha^{-1} × 11 plant m^{-2}	121.55 a	112.88 a	36.53 ab	1.41 b	778.14 ab	3312.1ab	67.49 bc
160 kg ha^{-1} × 5.5 plant m^{-2}	72.6 e	86.26 ab	47.43 a	1.02 d	621.43 cd	3004.8abc	76.26 a
160 kg ha^{-1} × 7.5 plant m^{-2}	92.87 c	103.55ab	28.93 b	1.23 c	744.32 abc	2906.9abcd	69.67 abc
160 kg ha^{-1} × 11 plant m^{-2}	125.03 a	113.13 a	32.19 b	1.61 a	818.78 a	3612.00a	68.63 bc
200 kg ha^{-1} × 5.5 plant m^{-2}	66.27 g	60.4 b	34.67 ab	0.97 de	459.22 ef	2047.2de	70.41 abc
200 kg ha^{-1} × 7.5 plant m^{-2}	84.12 d	84.56 ab	28.05 b	1.12 cd	549.21 de	2349.5cde	69.7 abc
200 kg ha^{-1} × 11 plant m^{-2}	110.55 b	95.73 ab	32.03 b	1.39 b	693.28 abcd	2974.4abc	67.55 bc

Numbers with the same letters in each column, have no significant differences to each other.

Discussion:

Increase in nitrogen application amounts up to a definite point, increases stolons including tuber but beyond that, reversely decreases them. In some studies, it has been shown that number of stolon in suitable nitrogen levels, was significantly more than other levels. Also, it has been approved that with increasing nitrogen amounts, number of tuber was increased (Khajehpour, 2006). It is clear that with increasing plant number, numbers of stems grown from the planted tuber, and consequently, number of produced tubers per stem, are increased. Thus, increase in plant density leads to increase in produced tubers (Khajehpour, 2006). Over-application of nitrogen may result in decrease in yield. This may attributable to the fact that in such conditions, vegetative growth of the aerial parts can be increased and hence, prevented transferring of photosynthetically matters into the storage parts (Tubers). Marguerite *et al*. (2006) and Alam *et al*., (2007) revealed that tuber yield per unit area was increased with increasing nitrogen fertilizer up to suitable level. According to the Jamaati-e-Somarin *et al.* (2009), in high densities, number of tuber and yield of potato is increased. Same to the tuber yield, tuber dry weight is affected by rates of nitrogen application and is increased with increasing nitrogen. (1; 13). This increase is probably due to increase in number of stolon, number of tuber and tuber yield. With regard to the fact that with increasing plant density, the number of produced tuber is increased, it can be said that increase in number of tuber may result in increase in tuber dry weight per unit area whereas, increase in density, increases the competition between and within the plants and hence, leads

to decrease in availability of nutrients for each plant and consequently, results in decline of mean tuber weight (Karafyllids *et al*., 1997). Applied nitrogen less affects number of tuber but more affects tuber size and increases it so, directly increases mean tuber weight but in condition of excess rates of nitrogen, mean tuber weight is decreased (Koochaki and Sarmadnia, 2001). Alvin *et al*. (2007) showed that with increasing plant density, plant dry matter was decreased in each plant but increased per unit area. It can be said that all factors affecting tuber yield, affect total plant dry matter, as well (Hashemidezfooli *et al.,* 1998). Based on the results, with increasing plant density, harvest index was decreased and vice versa. Since, both total plant dry matter and dry weight of tuber were increased but this increase for total plant dry matter was more than tuber dry weight, this trait was decreased. Also, Cox and Cherny (2001) found that with increasing density, harvest index is decreased. Arnout van Delden (Arnout, 2001) revealed that high rates of applied nitrogen can increase tuber dry weight. This finding approves our results on tuber dry weight and hence, we see that harvest index is increased with increasing nitrogen rates. On the contrary, Osaki *et al* (1995) stated that effect of nitrogen on biological yield is higher than economical one. In addition, it is obvious from the results that increase in dry weight of tuber at the highest rate of nitrogen, is less than total plant dry matter. So, it can be the reason of this fact that with increasing nitrogen up to 200 kg ha^{-1}, harvest index was decreased.

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