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Response of Growth and Yield of Potato Crop Cultivars to Nitrogen Levels

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Abstract: In order to evaluate responses of two potato cultivars to different nitrogen levels, a split-plot design based on randomized complete block design with four replications was conducted at agricultural research field, Ardabil, Iran in 2008. Main-plots included nitrogen levels: 0, 80, 160 and 200 kg ha^{-1} nitrogen and sub-plots were assigned to Agria and Satina cultivars. Measured traits were mean tuber weight, tuber yield and number of tuber were sorted according to size and harvest index. Results showed that cultivar Agria in all traits was superior to Satina except for the number of small size tubers. The highest mean tuber weight and tuber yield was observed using 160 and 200 kg ha^{-1} nitrogen. With increasing nitrogen levels, number of tubers larger than 55 mm was increased. The rate of 160 kg ha^{-1} nitrogen resulted in the tubers ranged between 28 and 55 mm. Agria cultivar gained more leaf biomass during the season than Satina cultivar 160 kg ha^{-1}, N produced the highest and control, produced the lowest biomass, respectively. The highest leaf biomass was obtained 83 DAP and finally decreased because of senescence and falling of leaves. Impact of nitrogen was not significant on small size tubers. Also, cultivar Agria had the highest values for most traits in treatment of 160 kg ha^{-1} nitrogen.

Key words: Leaf biomass, harvest index, nitrogen, potato, yield

INTRODUCTION

Potato (*Solanum tuberosum* L.) is grown and concerned in majority of countries 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 (Stephen, 1999). Increase in yield of potato such as other crop plants, is one of the most important purpose of the researchers to cope with the food need of the country. As the significance, potato is placed in the order of wheat, maize, rice and potato. Optimum consumption of fertilizers, especially nitrogen is of the great importance in plant yield increase but this have made large problems for the agricultural section of the country because of inadequate information about sufficient application of different fertilizers and hence, not obtaining favourite yields as a result of over-application of nutrient elements. Furthermore, this has led to accelerate of decomposition of organic matters and decrease in its rate in the soil, degradation of soil structure and consequently, decrease in soil fertility. Soil hardness in the majority of fields caused by the improper (high) application of fertilizers at present is an important issue which farmers are confronting. Favourite growth and yield of potato associates with the various such as nitrogen and plant genetics. Carter and Bosma (1974) found that there may be adverse relations between tuber and plant aerial parts growth

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so that, nitrogen application stimulates growth of aerial parts and delays tuber initiations. In addition, nitrogen has different effects on tuber. Various experiments have shown that number of tuber, weight, size and yield of tuber is affected by nitrogen application (Cole, 1975). Beraga and Caeser (1990) and Kleinhenz and Bennet (1992) reported that nitrogen fertilizer increases potato yield via increase in large tuber production. Same results have been reported by Jenkins and Nelson (1992). Beraga and Caeser (1990) showed that using high levels of nitrogen, very small tubers were increased, very large ones decreased and photosynthetically matters allocated to expand vegetative growth. Tuber weight in late-mature cultivars increased more than early-mature cultivars but in case of excessive nitrogen values, fresh tuber weight highly is decreased and in late-mature cultivars which have long-period of tuber initiation, development and growth of tuber is placed at different growth stages (Ankumah *et al*., 2003) and the majority of tuber initials may remain very small and disappear after a while and hence, number of tubers may change during the growth period (Zrust and Juzl, 1996). Tuber size is affected by the length of growth period of potato (Vos, 1995) time of tuber initiation (Ankumah *et al*., 2003) and the rate of applied nitrogen (Struik *et al*., 1990). Tuber size in various cultivars is different as this trait follows genetically aspects of plant more than any other factor (Kleinhenz and Bennet, 1992) but also, depends upon factors such as applied nitrogen (Struik *et al*., 1990). Number of large tubers per unit area in late-mature cultivars is more than early-mature ones. Number of tubers produced in the plant is increased and at early season, mean tuber weight and yield is lesser than late season. According to the several findings, mean tuber weight in late-mature cultivars is more than early mature ones. Applied nitrogen less affects number of tuber but mainly affects tuber size and eventually, larger tubers cause increase in mean tuber weight (Struik *et al*., 1990) but if applied nitrogen is higher than favourite rates, both mean tuber weight and number of tuber is decreased (Kleinhenz and Bennet, 1992). Mean tuber weight at optimum nitrogen levels is higher than other values. On the other hand, nitrogen fertilizer in early-mature cultivars increases mean tuber weight than late-mature ones, but in general, because of increase in the number of tubers, final yield in late-mature cultivars is higher than early-mature cultivars (Kleinhenz and Bennet, 1992). Optimum values of nitrogen in late-mature cultivars more than other values, significantly increases tuber size (Vos, 1995).

The aim of this study was to determine the required nitrogen values for potato cultivars to get high yields.

MATERIALS AND METHOD

This experiment was done at the agricultural research and natural resources station of the Ardabil, Iran with longitude of 48° 15′ and latitude of 38° 15′ in 2008. Ardabil Region has very cold winters, rainy springs, dry and warm summers and with annual precipitation 400 mm yearly (Jamaati-e-Somarin *et al*., 2009). Soil texture comprise of 46.5% clay, 27.5% silt and 26% sand. Used cultivars were (late-matured) Agria and (early-matured) Satina. Experiment was carried out as a split-plot design based in Randomized Complete Block Design (RCBD) with four replications. In this study two factors were involved; first was nitrogen levels (0, 80, 160 and 200 kg net N ha^{-1}) as a main-plots and second was cultivars (Agria and Satina) were assigned as sub-plots so, each block comprised of 8 plots of 22.5 m^2. Sub-plots contained 6 rows tubers were sown at a depth of 10 cm on 10th of may 2008. Rows were spaced approximately 75 cm to each other. Distance between the tuber seeds within the rows was 25 cm. Tuber seed average weight was 60-70 g. One meter between main and sub-plots as boarder effect was allocated. Nitrogen was applied at two stages:

- Application at planting time as 50% of total nitrogen
- Application at earthing up stage (60 days after planting) of the second half of nitrogen (Jamaati-e-Somarin *et al*., 2009)

Before harvesting at the time of 50% of aerial parts were dried (Khajehpour, 2006) vegetative parts were removed 10 days prior from harvest and all tubers were harvested. During the growing season, six sampling times were conducted in the order of: 57, 70, 83, 94, 105 and 118 Days After Planting (DAP). In each sampling, 5 plants were completely harvested from the plots along with the stems and tubers. Leaves were removed from stems and were placed in oven at 75°C for 48 h to constant weight (Jamaati-e-Somarin *et al*., 2009). Then, these dried leaves were weighed at the accuracy of 0.001 g and the recorded data were assigned as leaf biomass. Sampling was done from 2 m^2 plot area. Afterwards, tubers were then transferred to the laboratory, washed with running water along with the roots and stolons. Then, several plant sections such as tubers, stems, leaves etc and weighed. Fresh weight of tubers harvested from 2 m^2 was allocated as tuber yield. Tuber's diameter was measured and graded as small, medium and large (<28 mm, 28-55 mm and >55 mm) and were counted and different plant tissues separately were dried for 48 h at 75°C and weighed. These dry weights were used to determine harvest index as follows (Khajehpour, 2006):

$$\text{Harvest index} = \left(\frac{\text{Economic yield}}{\text{Biologic yield or total biomass}}\right) \times 100$$

All obtained data were subjected to variance analysis by SAS (6.1 version) and graphs and tables were drawn using Excel software. Mean comparisons of simple and interaction effects were made using Duncan multiple range tests at 5% probability level (Jamaati-e-Somarin *et al*., 2009).

RESULTS

Tuber Yield Per Plant

Effects of cultivar and nitrogen treatments and their interaction effects on tuber yield were found significant. According to results, it was showed that Agria cultivar with the yield of 981.6 g $plant^{-1}$ was superior to the Satina of 853.15 g $plant^{-1}$. The highest tuber yield per plant was obtained with application of 160 kg N ha^{-1}. Nitrogen rates of 200 and 80 kg N ha^{-1} were not significantly different (Table 1). Interaction effects of cultivar and nitrogen showed that the highest tuber yield was for Agria cultivar which had received 160 kg N ha^{-1}. On the other hand increasing in nitrogen cause insignificant increase in nitrogen rate from zero to 160 kg N ha^{-1} caused significant effect on yield, while increasing resulted in decreasing and was more pronounced in Agria cultivar. Increase in nitrogen values up to 200 kg N ha^{-1} in both cultivars reduced the yield and amount of this reduction in Agria cultivar was greater.

Mean Tuber Weight

Effect of cultivars, nitrogen levels and their interaction on mean tuber weight were significant. Agria cultivar produced higher mean tuber weight significantly than Satina (Table 1). Among nitrogen

Table 1: Effect of cultivars and nitrogen levels on potato tuber characters

				Tuber No.			
Factors	Levels of factors	Mean weight of tuber $plant^{-1}$ (g)	Tuber yield $plant^{-1}$ (g)	< 28	between 28-55 (mm)	> 55	Harvest index
Cultivars	Agria	95.6a	981.6a	0.93b	5.63a	4.36a	51.90a
	Satina	86.6b	853.1b	1.30a	4.63b	4.04b	49.17b
Nitrogen	0	66.0d	679.0c	1.68a	3.65b	2.51c	43.14c
(kg ha^{-1})	80	83.7c	868.0b	0.88b	5.46ab	4.08b	48.68b
	160	112.5a	1168.0a	1.16b	6.92a	4.46b	56.00a
	200	102.3b	952.5b	0.77b	4.50b	5.75a	54.31a

Whithin each characters, column sharing with the same letter(s) are not significantly different at 5% levels according to DMR test

Table 2: Effect of cultivars and nitrogen levels interaction on potato tuber characters

Interactions of cultivar×nitrogen (kg ha^{-1})	Mean weight of tuber plant^{-1} (g)	Tuber yield plant^{-1} (g)	Tuber No. < 28 (mm)	Tuber No. Between 28-55 (mm)	Tuber No. > 55 (mm)	Harvest index
Agria×0	68.92e	698.5d	1.30b	4.10d	2.95cd	41.8d
Agria×80	85.24d	868.8c	0.75de	5.85b	3.85bc	52.2b
Agria×160	119.20a	1354.0a	1.02c	7.75a	4.85ab	59.5a
Agria×200	109.10b	1006.0b	0.67e	4.85c	5.80a	54.0b
Satina×0	63.18e	659.5d	2.07a	3.20e	2.07d	44.4cd
Satina×80	82.22d	867.3c	1.05c	5.07c	4.32b	45.1c
Satina×160	105.80b	973.4bc	1.30b	6.10b	4.08bc	52.4b
Satina×200	95.46c	912.4bc	0.87cd	4.15d	5.70a	54.6b

Whithin each characters, column sharing with the same letter(s) are not significantly different at 5% levels according to DMR test

tuber weight (Table 1). With regard to interaction effects of cultivar and nitrogen, it was found that the highest mean tuber weight in both cultivars was obtained at 160 kg N ha^{-1} and control treatment resulted in the lowest mean tuber weight. Agria cultivar produced more tuber weight than Satina cultivar at all nitrogen levels.

Number of Tubers Less than 28 mm in Diameter

Number of tubers smaller than 28 mm was affected by cultivars, nitrogen levels and their interaction. Mean comparisons showed that Satina cultivar was superior to Agria cultivar in this trait. Interaction effect of nitrogen and cultivar (Table 2) revealed that Satina cultivar with no N fertilizer gave highest value. In both cultivars, with increasing nitrogen levels, number of tubers smaller than 28 mm was decreased. It is notable that this is undesirable trait in potato production.

Tuber Numbers Between 28-55 mm in Diameter

Effect of nitrogen ($p<0.05$), cultivar and their interaction ($p<0.01$) on this trait was significant. Results showed that Agria cultivar caused more tubers ranged between 28-55 mm than Satina. Also, using 80 and 160 kg N ha^{-1} resulted in the highest rate of this trait which had significant difference with amount of 200 kg N ha^{-1} and control. Application of 160 kg N ha^{-1} caused number of 6.925 tubers which was the highest number and was placed in same group with 80 kg N ha^{-1}. Also, we found that according to the interaction effect, treatment of Agria×160 kg N ha^{-1} gave significantly higher value. With increasing nitrogen levels from control to 160 kg N ha^{-1}, this trait was mainly increased and beyond that, up to 200 kg N ha^{-1}, it was decreased.

Number of Tubers Larger than 55 mm in Diameter

Nitrogen had significant effect on number of tubers larger than 55 mm ($p<0.05$). Results showed that increasing in applied nitrogen from control to 200 kg N ha^{-1}, caused increasing in tubers larger than 55 mm so that, control and 200 kg N ha^{-1} obtained the least and the greatest value, respectively. Levels of 160 and 80 kg N ha^{-1} had the similar effect. Interaction effect of nitrogen levels and cultivars at the level of 200 kg N ha^{-1} was significant for both cultivars. In both cultivars tuber numbers from control to 200 kg N ha^{-1} increased and maximum number was obtained at 200 kg N ha^{-1}. Agria×160, Agria×200 and Satina×200 kg N ha^{-1}.

Harvest Index

Effect of cultivar, nitrogen and their interaction on this trait were significant. Results indicated that Agria cultivar had the highest harvest index (51.9%) and was superior to Satina cultivar. Nitrogen levels of 160 and 200 kg N ha^{-1} had the significant differences with the others. In general, with

increasing nitrogen application, this trait increased and the highest value was obtained of 56% in treatment of 160 kg N ha^{-1}. Also, the highest tuber yield was observed at this level and the lowest one for control. With regard to the interaction effect, application of 160 kg N ha^{-1} with Agria cultivar caused the highest value of 59.52% which resulted in highest value. Satina cultivar at control was superior to Agria cultivar but with increasing nitrogen rates up to 160 kg N ha^{-1}, Agria cultivar surpassed Satina. Both cultivars at 200 kg N ha^{-1} showed decrease in HI.

Leaf Biomass

Results showed that Agria cultivar produced more leaf biomass during the season than Satina cultivar (Fig. 1) which reflected in more yield of this cultivar. The highest leaf biomass was obtained 83 DAP and finally decreased because of senescence and falling of leaves. Investigation of different nitrogen levels showed that 160 kg N ha^{-1} produced the highest and control produced the lowest biomass, respectively (Fig. 2). Maximum biomass for both cultivars was observed at 160 kg N ha^{-1}. Also, difference between cultivars was great at this level. Effect of nitrogen level and cultivar on this trait was significant (Fig. 3). During growth period, control showed the lowest biomass. Increase in biomass for all treatments 83 DAP was intense but leaf biomass at 160 and 200 kg N ha^{-1} decreased after that time. Against this, leaf biomass at control and 80 kg N ha^{-1} were stable from 83 to 105 DAP and decreasing of biomass was happened 105 DAP.

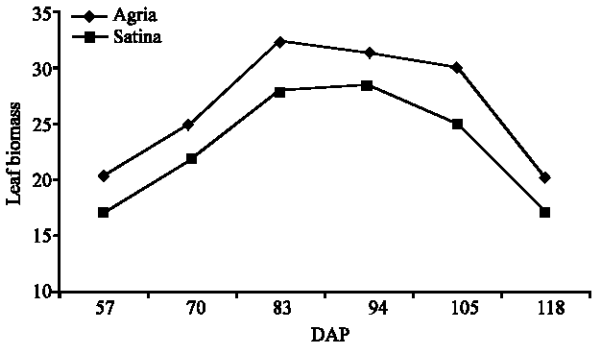

Fig. 1: Changes of leaf biomass with time. DAP: Day after planting

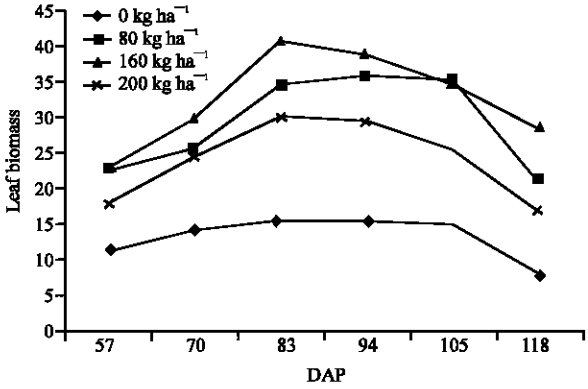

Fig. 2: Effect of nitrogen levels on leaf biomass with time. DAP: Day after planting

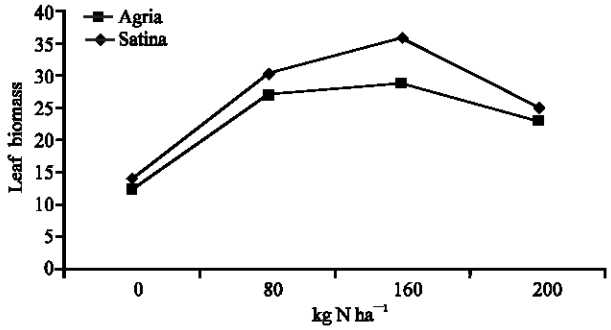

Fig. 3: Interaction effect of N×Cv on leaf biomass

DISCUSSION

In majority of plants, increase in applied nitrogen results in increase in yield, Jamaati-e-Somarin *et al*. (2008) revealed that tuber yield per plant was increased with increasing nitrogen fertilizer up to suitable level (160 kg N ha^{-1}). This trend is nearly visible in the potato but it is shown that the highest value of nitrogen could not increase tuber yield than previous level. It is likely because of nitrogen allocation to aerial parts in higher levels than tubers. Also, Love *et al*. (2005) showed that there were differences between cultivars concerning tuber yield. Different cultivars have different reactions against nitrogen application in terms of improving tuber yield as nitrogen is increased. It is obvious that Agria cultivar has more significance response to yield increasing. The only reason for this phenomenon is that this cultivar is of late-mature ones (compared to the Satina) and produce more yields receiving higher fertilizers relative to early-mature ones. As the mean tuber weight is a function of tuber yield per plant, in this case must be similar to the earlier described function. It seems that cultivars with long growth period have more leisure to complete tuber initialization and storage of photosynthetically matters in tubers. Probably, allocation of greater amounts of photosynthetically matters into the tubers at 160 kg N ha^{-1} has led to increase in tuber weight and subsequent tuber yield because; excessive rates of nitrogen may allocate photosynthetically matters into the aerial parts instead of tubers. Applied nitrogen have little affects on of tuber but affects tuber size and increases it and directly increases mean tuber weight but in case of excessive rates of nitrogen, mean tuber weight is decreased (Jamaati-e-Somarin *et al*., 2008, 2009).

In terms of tuber size, investigation of nitrogen levels indicated that the number of tubers smaller than 28 mm in control treatment significantly was more than the other treatments. These three levels were placed in the same group with insignificant difference to each other. Contrary to this result, Beraga and Caeser (1990) found that at high nitrogen levels small tubers appeared more than that of low levels and in this case, photosynthetically matters were transferred to the aerial parts. On the other hand, increase in tuber size was more remarkable for Agria than Satina cultivar. This is completely a favourable trait for potato production and has direct relation with yield. Tuber yield in this treatment (Agria×160 kg N ha^{-1}) was the highest. Based on the several reports, number of large size tubers per unit area is higher in late-mature cultivars than early-mature ones. Tuber size not only depends on cultivar and physiological age of mother tubers (Zrust and Juzl, 1996), but also on soil and temperature. Jenkins and Nelson (1992) reported that nitrogen increases the number of large tubers per plant and hence, increases tuber yield.

Osaki *et al*. (1995) that reported maximum harvest index was obtained at low nitrogen amounts, in this study maximum HI in early-mature cultivar (Satina) and late-mature cultivar (Agria) were obtained at 200 and 160 kg N ha^{-1}, respectively and lower nitrogen gained less HI. In all plants, leaf

is an important part because the majority of photosynthetically matters are produced by them. The more leaf growth at early season, the higher the probability of yield gain is resulted. In order to calculate leaf dry weight during the growing season samplings of 57, 70, 83, 94, 105 and 118 days after planting were done.

CONCLUSION

Results showed that early-mature and late-mature cultivars had differences to each other in terms of tuber size, number and yield. The Agria cultivar obtained higher tuber yield than the Satina on account of higher the HI, number of tubers between 28-55 mm and the mean tuber weight. In both cultivars maximum tuber yield was obtained at 160 kg N ha^{-1} and increase in nitrogen up t o 200 kg N ha^{-1} decreased tuber yield. The most important result obtained was to determine the appropriate amounts of nitrogen fertilizer in potato farming because excess values of this nutrient can either reduce yield or increase cultivation costs without more benefits. Also, it is suitable to cultivate late-mature cultivars of potato in terms of capability of them to use favorably agricultural incomes leading to yield increase. Therefore, with regard to this study, application of 160 kg N ha^{-1} and the late-mature cultivars (Agria) to obtain maximum yield is recommended.

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