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Effects of Different N Fertilizer Rate on Starch Percentage, Soluble Sugar, Dry Matter, Yield and Yield Components of Potato Cultivars

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Abstract: Nitrogen (N) fertilizer management is a challenge in potato production. Therefore, a study was carried out on the effect of different nitrogenous fertilizer (urea) levels on yield, yield components and tubers quality in terms of starch and dry matter percentage of different potato cultivars in 2010. It was a factorial experiment based on a Randomized Complete Block Design with three replications. The main plot was three fertilizer levels (0, 100 and 200 kg elemantal N/ha) and the sub-plot was potato cultivars (Agria, Marfona, clone B5 and clone B6). The results showed that the main effect of cultivar was significant on tuber mean size, fresh tuber yield-ha^{-1} and starch content at 1% probability level. Also, the main effect of N fertilizer was significant on tuber number-plant^{-1}, tuber mean size, fresh tuber yield-ha^{-1}, starch content and dry matter content at 1% probability level. Means comparison showed that the application of 100 kg N/ha had a significant effect on tuber number-plant^{-1}, fresh tuber yield, starch content and dry matter content and ranked in the superior group. In terms of starch percentage, clone B5 with mean starch percentage of 14.42 ranked in the superior group and in terms of dry matter percentage, cv. Marfona and clone B5 ranked in the superior group *a* together. With the increase in N fertilizer level from 100 to 200 kg/ha, not only reduced fresh tuber yield and other traits, but also there was a significant decrease in measured traits.

Key words: fertilizer; nitrogen; starch; yield components; soluble sugar; potato.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a tuber produce whose tubers are carbohydrate-rich source with an important role in feeding people and is of interest because of its very high yield/ha, so that it produces as much protein and about twice as much carbohydrate as grains. Its tuber is economically valuable and is extensively used in feeding people and livestock and in starch production. In terms of production, potato ranks second after wheat in Iran (Suzuki *et al*., 1994) and its energy and protein production/unit area is greater than that of wheat and rice because of its high yield (Khajehpour, 2004). A challenge in potato production is effective management of nitrogenous fertilizers (Fageria *et al*., 2005). Nitrogen is the most essential element in increasing crop yields; thus nowadays, nitrogenous fertilizers are extensively used worldwide (Fageria *et al*., 2005). Nitrogen is an essential element in crop growth and makes an important constituting component of proteins. When grown under unusual conditions (e.g. N fertilizer over-application), a plant produces less protein and accumulates non-protein N. Nitrate is one of the non-protein forms whose excessive application in diet could be poisonous (Hernandes, 2000). Average per capita potato use is 35 kg in Iran which is increasing; given the growing population and costliless of other foodstuff, increasing potato production is unavoidable (Rezaee and Sultani, 1996). Potato tuber production consumes 4.5-8.5 kg soil N/t (Yazdandoust-e Hamadani, 2003) and in total, nitrogen constitutes 1-5% of plant tissues. A plant absorbs most nitrogen in nitrate form. Nitrogen is an important and essential structural component of chlorophyll and various proteins (Koochaki, 2006). Starch is an essential component of potato constituting 17-21% of its fresh weight and about 80% of its dry matter. It is nutritional reserve of most plants and starch granules are in fact compressed packages of glucose polymer (Kaur *et al*., 2002). In total, starch characteristics are influenced by variety and environmental conditions such as precipitation amount and its distribution over growing season and temperature range during potato growth and all these factors result in the diversity of the characteristics of the starch produced by potato plants grown under different climate conditions (Sasaki *et al*., 2000). In a study on the effect of harvest date on starch characteristics in some potato cultivars, Takahiro *et al*. (2004) stated that late harvest increased average granule size, phosphor content and viscosity while slightly decreased amylase level.

Application of extraneous nutrients like fertilizers is necessary in potato production because its high rate of dry matter production rapidly discharges soil nutrients (Imas and Bansal, 1999). The research shows that adequate nitrogen application in growing season is required to realize high potato yield and quality. However, application management and appropriate amount of application in potato cultivation is a subtle task. Under- or

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over-application of nitrogen or its early or late application adversely affect its produced tubers. N deficiency decreases growth and yield and N excessive application stimulates shoot growth, retards tuber formation and filling period, decreases tuber specific weight and shortens tuber storage time (Rezaee and Sultani, 1996; Westerman *et al*., 1985).

Since growers have realized the considerable effects of N on plants vegetative growth, they usually apply N fertilizers more than needed which brings about environmental pollution due to nitrate leaching in addition to increasing the production costs and decreasing the maximum profit (Moosavifazl and Faeznia, 2001). Osaki *et al*. (1992) indicated that application of 0-300 kg N/ha increased tuber number/plant and tuber size.

Waddell *et al*. (1999) reported that N fertilizer application increased tuber yield compared with control. In a research, mean increase in potato tuber yield was brought about by application of 34% N fertilizer (Marguerite *et al*., 2006). Abbasi *et al*. (2005) reported that optimum application of N fertilizer increased plant dry weight, tuber number, tuber weight and tuber qualitative and quantitative characteristics, but its over-application regarded growth and decreased tuber qualitative and quantitative characteristics. Shahbazi (2004) and Saeedi (2007) showed that optimum application of N fertilizer increased potato yield but its over-application decreased tuber weight, number, dry weight and yield. Given the necessity of supplying optimum amount of nitrogen for potato growth as one of the most important industrial crops in the world and its undesirable growth under N over- and under-application, the objectives of the current study were to examine potato growth under different N levels and to find out the optimum N level as well as to examine the effects of various N fertilizer levels on starch percentage, yield and yield components of different cultivars.

MATERIALS AND METHODS

To study the effects of different N levels on starch percentage, yield and yield components of different potato cultivars, a factorial study was carried out based on Randomized Complete Block Design with three replications in experimental field of Agriculture Department, University of Mohagheghe Ardabili, Ardabil, Iran in 2010. The factors included N fertilizer levels (urea source) at three levels of 0, 100 and 200 kg pure N/ha applied in two stages of planting and cultivation and the second factor was potato cultivars at four levels of Agria, Marfona, clone B5 and clone B6.

The plots were composed of six 5-meter-long rows with inter-plot spacing of 1.5 m to avoid the interference of fertilizer in the adjacent plots. To determine the yield and to measure the traits, an area of 2 m^2 of each plots was harvested after eliminating margins and the extremes of the rows. Before traits measurement, the tubers with roots and stolons were completely washed with water and then, rinsed with distilled water. Also to determine dry weight of organs, the samples were separately put in ventilated ovens for 48 hours at 75°C until stabilization of the weight of samples. To extract the starch, the samples were completely chopped with mincer; then, they were mixed with water with an amount of three times pulp weight, 20 ml metabisulphite solution 0.1% was added and was filtered by gauze. When the solution was separated into two phases, the starch was separated by filter paper and Büchner funnel and starch percentage was calculated in terms of initial fresh weight (Takahiro *et al*., 2004). The soluble sugar percentage was measured by Anthrone method (Irigoyen *et al*., 1992). The data were analyzed by software SAS and the means were compared by Duncan Test at 5% level.

RESULTS AND DISCUSSION

Mean Tuber Number/plant:

The main effect of cultivar on mean tuber number/plant was not significant; that is, the studied cultivars did not have significant differences in their mean tuber number/plant. Jami Moayani *et al*. (2009) concluded that there were significant differences among potato cultivars in their mean tuber number/plant. The main effect of N fertilizer as well as N fertilizer × cultivar interaction was significant at 1% probability level (Table 1). Also, means comparison table (Table 3) showed that all four studied cultivars had no significant differences in their mean tuber number/plant and were ranked in same group. Also among different N fertilizer levels, application of 100 kg pure N/ha was better than the other two levels and was ranked in the superior group. In N fertilizer × cultivar interactions, the cultivars B5 and B6 were produced the highest mean tuber number/plant at N level of 100 kg/ha and were ranked in superior group *a*. This is in agreement with foregoing researches (Saeedi, 2007; Koochaki, 2006).

Mean Tuber Diameter:

Analysis of variance (Table 2) showed that the main effects of cultivar, N fertilizer and cultivar × N fertilizer interaction were significant on mean tuber size at 1% probability level. The cultivars Agria and Marfona were ranked in superior group with mean tuber sizes of 5.23 and 5.38 cm, respectively. Among N fertilizer levels too, application of 200 kg N/ha gave rise to the greatest mean tuber size. Among the interactions too, the cultivar Marfona at N level of 200 kg/ha ranked in the superior group (Saeedi, 2007).

Table 1: Soil characteristics examined at the depth of 0-30 cm.

Texture	Total N percentage	Total lime percentage	Saturation percentage	Organic matter percentage	Organic carbon percentage	pH	Total saturated EC (mmhos/cm)
Loom-sandy	0.056	13.75	47.98	2.01	1.17	7.09	2.68

Table 2: Analysis of variance of effect of different N fertilizer levels on different traits of potato cultivars.

Sources of variance	df	Mean tuber number	Mean tuber size	Fresh tuber yield	Starch percentage	Dry matter percentage	Soluble sugar percentage
Replication	2	0.21^{**}	0.36	1339.83^{*}	4.96^{*}	7.93^{**}	0.22
Cultivar	3	0.10	4.3^{**}	2667.36^{**}	6.85^{**}	2.76	0.01
N fertilizer	2	0.86^{**}	3.1^{**}	5683.98^{**}	13.28^{**}	15.01^{**}	0.24^{*}
Cultivar × N fertilizer	6	0.19^{**}	1.93^{**}	10582512^{**}	4.88^{**}	3.52^{**}	0.06
Experimental error	22	0.06	0.23	365.81	1.27	1.10	0.07
C.V. (%)	-	3.14	10.14	15.86	9.42	9.29	22.68

* and ** show significance at 5% and 1% probability level.

Table 3: Means comparison of effect of different N fertilizer levels on different traits of potato cultivars.

Source of variations	Mean tuber number/plant	Mean tuber diameter (cm)	Fresh tuber yield (t/ha)	Starch percentage (%)	Dry matter Percentage (%)	Soluble sugar percentage (%)
Cultivars						
Agria	3.88 a	5.23 a	15.711 b	13.19 bc	16.16 b	1.12 a
Marfona	3.57 a	5.38 a	20.092 a	12.33 c	16.30 ab	1.22 a
B5	4.53 a	4.54 b	15.190 b	14.42 a	17.29 a	1.20 a
B6	4.61 a	3.85 c	10.537 c	13.62 ab	17.05 ab	1.22 a
N fertilizer levels						
0 kg/ha	3.05 c	4.22 c	10.068 c	12.22 b	15.58 c	1.04 b
100 kg/ha	5.24 a	4.79 b	20.733 a	14.27 a	17.82 a	1.20 ab
200 kg/ha	4.15 b	5.24 a	15.348 b	13.68 a	16.70 b	1.33 a

Fresh Tuber Yield:

Analysis of variance (Table 2) showed that the main effect of cultivar, N fertilizer and cultivar × N fertilizer interaction was significant on fresh tuber yield at 1% probability level. Among cultivars, the cultivar Marfona ranked in the superior group with the highest fresh tuber yield followed by the cultivars Agria, B5 and B6, respectively. Also among fertilizer levels, the fertilizer level of 100 kg had the strongest effect on fresh tuber yield and produced the highest yield. Among the interactions too, the cultivar Marfona at fertilizer level of 100 kg N/ha ranked in the superior group and the cultivar B6 at no-fertilizer level ranked in the inferior group. The increase in the application of N fertilizer up to a certain level increases the potato yield, but since then, it has no effect on the increase in yield (Westerman *et al*., 1985). According to the results, not only the unbridled application of fertilizers is not seemingly useful for crop, but also it is not cost-effective and even it may impose some injuries. Jindong *et al*. (2006) stated that if the amount of applied fertilizer is greater than field capacity, the excessive fertilizer leaches to underground waters, which is harmful to ecosystems. Therefore, the recommendation regarding fertilizer type and level for a crop and field must be based upon genuine and delicate experiments. While some believe that high levels of fertilizer maximizes the net efficiency by neutralizing the adverse effects of soil quality on yield, the research shows that high levels of applied fertilizer is responsible for the decrease in tuber yield, N use and recovery efficiency, the occurrence of tuber diseases and finally, the rise of nitrate leaching around potato fields (Li *et al*., 2003).

Starch Percentage:

The main effect of cultivar, N fertilizer and the interaction between them was significant on starch percentage at 1% probability level. According to means comparison table, cv. B5 ranked in the superior group with the highest starch content. The fertilizer level of 100 kg/ha had the strongest effect on starch content and among fertilizer and cultivar interactions too, cv. B5 at N level of 100 kg/ha ranked in the superior group. Since starch forms 60-80% of dry matter, there was a special correlation between starch content and tuber dry matter. As can be seen, the cultivars with the highest dry matter had proportionally the highest starch content too. Yaghbani *et al*. (2005) reported that there was significant difference between starch contents of different cultivars. Starch is the main compound of potato tuber, making 3/4 of dry matter and depends mostly on cultivar. It plays an important role in the quality of products and is an important factor affecting potato cooking quality (Jafarian, 2000).

Dry Matter Percentage:

The main effect of cultivar, N fertilizer and their interactions on dry matter percentage was significant at 1% probability level. Among cultivars, cv. B5 and among fertilizer levels, 100 kg/ha had the greatest effects on dry matter content and ranked in the superior group. The results were not in agreement with Moosavi *et al*. (2001) who reported that the effect of different N fertilizer level was insignificant on dry matter content. Krijthe (1982) reported that the excessive level of available N fertilizer stimulates reformation of tubers and may lead to the lengthening of tuber formation period and the difference in tubers maturity which in turn, leads to the difference in tubers dry matter content.

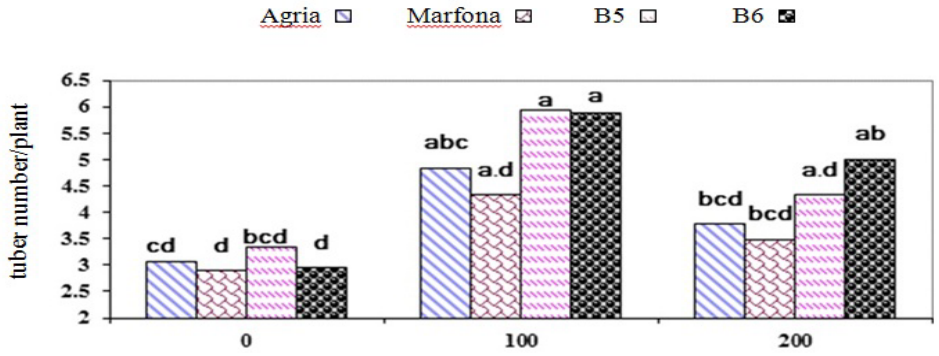

Fig. 1: Interaction between different N fertillizer levels and potato cultivars on tuber number/plant.

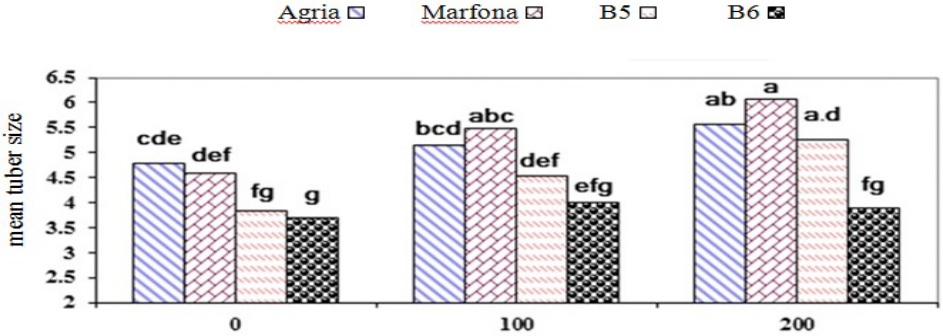

Fig. 2: Interaction between different N fertillizer levels and potato cultivars on mean tuber size.

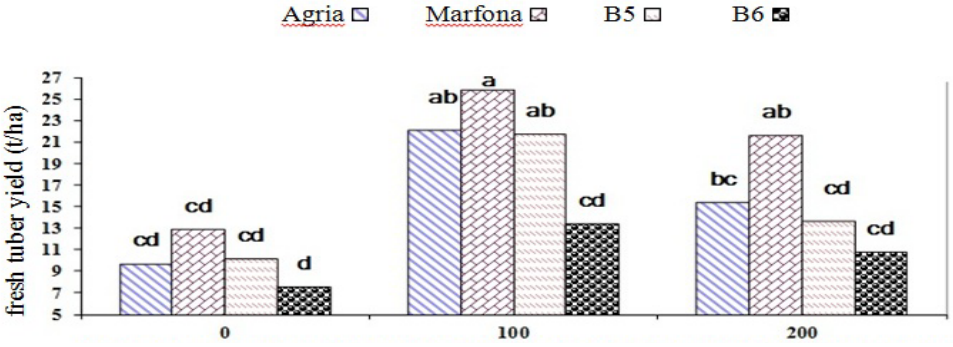

Fig. 3: Interaction between different N fertillizer levels and potato cultivars on fresh tuber yield.

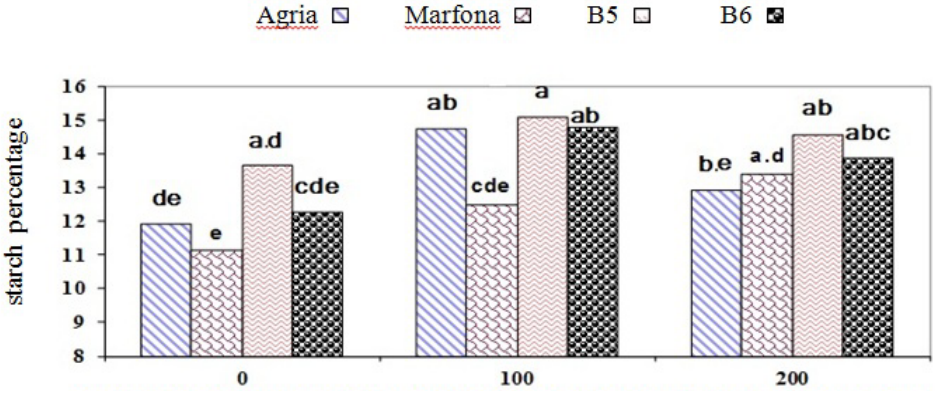

Fig. 4: Interaction between different N fertillizer levels and potato cultivars on starch percentage.

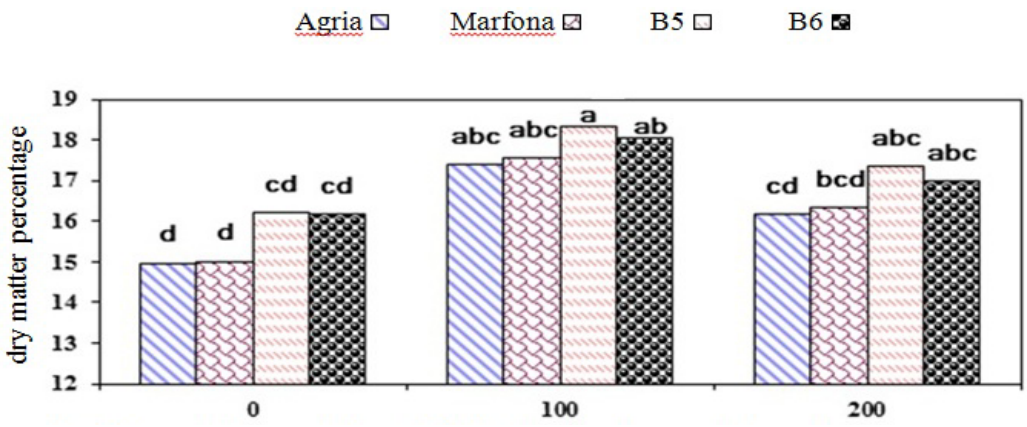

Fig. 5: Interaction between different N fertillizer levels and potato cultivars on dry matter percentage.

Soluble Sugar Percentage:

Analysis of variance table showed that the main effect of cultivar as well as the interaction between cultivar and fertilizer level was insignificant on soluble sugar percentage, but the main effect of N fertilizer level was significant on it at 5% probability level. Also, the table of means comparison showed that among fertilizer levels, the level of 200 kg N /ha ranked in the superior group producing the highest soluble sugar percentage (1.33%) followed by the level of 100 kg N/ha with soluble sugar percentage of 1.20% and finally, control with soluble sugar percentage of 1.04%. N fertilizer increased sugar percentage in potato tubers. Gharmehkhani *et al*. (2010) showed that cv. Satina had the highest content of starch, sucrose and energy while cv. Agria had the lowest starch and energy content and cv. Kennebec produced better products than the other two cultivars given its highest dry matter, appropriate specific weight and lower reducing sugars.

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