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Effect of nitrogen fertilizer levels on tuber filling rate and protein assimilation in early and late maturing potato

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ABSTRACT

One of the very important determinate methods in order to better use of nitrogen fertilizers is considering the differences belonging to growth period length in early and late maturing varieties. Surly, two different groups of potato including early and late maturing varieties would have different needs from the aspect of the optimum use rate of nitrogen fertilizer aspect. This experiment carried out in 2004 crop year in agriculture research station of Ardabil city, stated in 10kilometer far from this city in the east (Alarug village). The factors included four levels of nitrogen fertilizer (0, 80,160, and 200kg net nitrogen per hectare) in main plots and two varieties of potato including Agria (late maturing) and Satina (early maturing) in secondary plots. The experiment was conducted as split plot with randomized complete block design with four replications. The results of variance analysis, demonstrated that the main effects of nitrogen and variety was significant in most of the measured traits such as tuber yield per plant. By increasing fertilizer use to 160kg net nitrogen per hectare, tuber yield increased significantly in Agria variety comparing to Satina, and the most tuber yield in final harvest of late maturing Agria variety with 160kg nitrogen per hectare was estimated about 39.43tons per hectare. By increasing nitrogen use to 200kg nitrogen per hectare, tuber yield decreased significantly in both varieties. Results demonstrated that early maturing Satina variety has more tuber and shoot nitrogen percentage and uptake value compared to late maturing Agria variety. Protein percentage in Satina variety and protein yield in Agria variety had the highest value. By increasing nitrogen fertilizer levels, we observed a significant increase in the traits including nitrogen percentage and uptake value of tuber and shoot and also protein percentage.

Key words: potato, nitrogen, yield, protein

INTRODUCTION

Potato is one of the main food stuffs in people's nutrition regime all over the world. Most of the potatois used directly or in secondary products. In many countries, potato has been used as a main source of providing energy for human during long years. Potato contains 17 percent carbohydrate, 1 percent solutions, 2 percent protein, 0.1 percent fat and 0.6 percent fiber. Potato is also sometimes used to produce alcohol (khajehpoor, 1996). All the produced potato isn't used forhuman nutrition, but some is used as livestock food, some as seed and some for producing starch. Using potato for producing starch is very common in Holland, Eastern Europe and Japan (Ankoma etal., 2003).

Nitrogen is necessary for growth and production and is one of the main components of proteins. When a potato plant grows in aberrant conditions, protein production decreases and nitrogen accumulates in plant in the forms except protein. Nitrate is one of these forms which its extra use in plant nutrition regime would result toxicity. Nitrate toxicity is due to forming met.Hemoglobin which causes erythrocytes to lose their ability to transport oxygen (Hernands, 2000). Tubers are transformed stems that form the main parts of nutrient reserves in potato plant. On the

tuber surface eyes are disturbed spirally. Each eye is consisting of two or three buds and several axillary buds, which are in the axil of primary leaves (scales). Terminal bud is in the middle of eyes, which is surrounded by two leaves and some leaflets. The number and depth of the eyes, also depth, color and form of tuber vary in different varieties and cultivars of potato.

Carter and Busma (1974) reported that there is a reversed relationship between plants shoot and tuber growth. For example the factors like early irrigation and nitrogen use which promote growth of the shoot, postpone tuber setting. Different nitrogen levels have different effects on the tuber. Number of tubers (Prosba, 1988), tuber color, tuber average weight (Cool, 1975), tuber size, even the internal compounds and dry and humid weight of tubers differ influenced by the amount of nitrogen fertilizer used among various experiments done (Berga and Kaizer, 1990).

Cleanhenz and Benit(1992) declared that, nitro sgen increases the yield by its effect on the number of large size tubers. Seed size effects vegetation vigour of young potato plants. By increasing seed tuber size, the yield increases (Martin, 1995). Decreasing number of tuber is due to decrease in number of stolon, getting enough nitrogen results in stolon number increase (Moller Hogen, 1993). An experiment demonstrated that top-dressing of nitrogen doesn't have a significant effect on number of tubers but increases tuber weight and subsequently the yield significantly (Bohrani and Hooshmandi, 1998).Beginning tubers growth, the growth of other plant organs decrease and tubers are the only meristemicregionswhere mineral and organic materials accumulate. Growth curve of potato tuber is a sigmoid shapecurve and it usually consists of a long linear phase(Heris, 1982). The reaction to day length is usually highly adjusted by impact of other factors, especially by the amount of fertilizer. High amounts of fertilizer, especially nitrogen fertilizer, flourishes the growth of plants shoot and delays tuber formation verymuch (Ghasim, 1382). Tuber is the part of potato plant which is considered more than other organs of plant, and in fact organizes economic yield of this crop. A larg number of studies have been conducted on the way nitrogen fertilizer affects the number,size, dry weight and humid weight of tubers. All of these studies have impressed on significant effect of nitrogen fertilizer on these traits. Because of different reactions of potato tubers to different levels of nitrogen fertilizer, an adequate fertilizer recommendation is very difficult. In other hand sensitivity of this issue increases by interference of varieties considering time of maturity(early or late maturing variety) and length of growth period. Jozel(1989) reported that using nitrogen fertilizer increases the weight of the late maturing varieties more than early maturing varieties, but if nitrogen amount exceeds the optimum range, humid weight of tubers decreases severely. This decrease though will not be significant in early maturing varieties. The dry weight of tubers is less affected by amount of used nitrogen. The number of tubers shows a significant positive relation with total dry weight(Sadeghzadeh, Hemayati, 1996).

During short day conditions, formation of tubers starts earlier, stolons remain shorter and the shoots smaller. In long day conditions, the formation of tubers starts later, stolons grow longer and the shoots more. In some varieties, during long day conditions, growth of tubers doesn't occur (SadeghzadehHemayati, 1996). Each variety has a unique critical day length. Since formation of tubers is also influenced by temperature, day length of European varieties changes less than critical day length of early maturing varieties (Biokma and Anderzag, 1990). Short day length and low temperature usually promote tuber formation. In average and low temperatures, the effect of day length is much more on tuber formation time and also its effect on late maturing varieties is more than early maturing varieties. In high temperatures high amounts of nitrogen use can result in late tuber formation which can decrease the yield very much (HashemiDezfuli et.al, 1998).

In some varieties with long tuber forming time, development and growth of tuber occurs in different stages of plants growth (Ankoma et.al, 2003). There is a correlation between number of stolons and number of tubers. In late maturing varieties that tuber formation period is long, growth and development of tuber occurs in different stages of growth. Most of tuber primordials remain in very small sizes and resorbed by the plant after a while, hence the number of tubers may reduce during the growth period (Zerast and Jozel, 1996). Underground nodes alter considering the environmental conditions and variety (Evans, 1963). In the other hand it is influenced by agronomic practices such as cultivation depth, ridging and earthing up (Biokma and Anderzag, 1990). The numbers of tubers that grow on a plant are determined in the beginning of growing season. By increasing the yield during the growing season, average tuber size increases, too. In the beginning of the season, when the yield is low, average tuber size is small. The yield increases afterwards, but its increase isn't as much as average increase of tuber size. Biokma and Anderzag (1990) concluded that in the varieties with low yield, average tuber size is small, while it increases in high yield varieties. Using nitrogen has an important secondary effect and that is a delay in increase of tuber bulk. Different experiments demonstrate that average tuber weight in late maturing varieties is more than the early maturing. Although there are some reports that average tuber weight doesn't follow the time of maturity and mostly depends on amount of fertilizer used, genetic features, soil texture, amount of water used etc. (Gasoamy, 1995).

Studies of SadeghzadehHemayati (1996) demonstrated that in different levels of variety, average tuber size differed significantly in probability of 1 percent, except for the fifth sampling (127 days after sowing). In other word different varieties differed significantly from each other in average tuber weight. This difference was so much that it was seen in the beginning of the growing period.

Foranze (1990) reported that the increase of tuber yield and tuber dry weight by increasing fertilizer level from 80 to 120 kilograms net nitrogen per hectare was significant and by less than this amount the increase of yield and tuber dry weight was insignificant. By increasing fertilizer level from zero to 100 kilograms net nitrogen per hectare, tuber yield and tuber dry weight increased 2000 and 420 kilograms per hectare, respectively. An experiment during three years on Diamont, Aola and Moren varieties demonstrated that the best amount of nitrogen fertilizer in order to dry matter increase is 80 kilograms net nitrogen per hectare. Using nitrogen fertilizer can increase dry matter to a limited extent (Maghrur, 1997). The more dry matter percentage, the less water evaporates. Almost all the factors affecting total dry matter reserved in tubers, influence the tuber yield, too. The ratio of total dry matter of tuber to total weight of tuber is called dry matter percentage of tuber (Jenkins and Nelson, 1992). If a definite factor increases total dry matter of tuber more than its total dry weight, dry matter percentage will increase. In the opposite condition, dry matter percentage will decrease. Extra amounts of nitrogen especially if causes harvest of crop before natural maturity, may result a decrease in the amount of dry matter, increasing amount of reduced carbohydrates and may increase protein and nitrate (Falahati, 1997). Tuber dry matter differs about 13.1-36.8 percent (average 24 percent) of tuber humid weight. In different late maturing and early maturing varieties, separately, the amount of nitrogen used, has less effect on tuber dry weight per m^2 and dry matter percentage of tubers and this difference isn't usually significant (Rajana at.al, 1987). SadeghzadehHemayati (1996) reported that the value of tuberdry weight had a significant positive relationship with total dry weight during the growing period. This trait has also a significant positive relationship with harvest index By experiments conducted on four varieties of potato with two levels of nitrogen fertilizerZerast and Jozel (1996) indicated that leaf area duration and vegetative growth increased by increasing nitrogen fertilizer used. According to the results of these experiments tuber dry weight and total dry weight increased in all varieties due to the amount of nitrogen used. So that the most values for these traits acquired with 120 kilograms net nitrogen per hectare which was the last level of nitrogen fertilizer (Sadeghzadehhemayati, 1996).

MATERIALS AND METHODS

The experiment carried out in 2004 crop year in agricultural research station of Ardabil, stated in 10kilometers far from Ardabil in the east(Alarug village). It was conducted as split plot with randomized complete block design.

A. Is in main plot which includes: fertilizer with four levels: 0,80,160,200 kilograms net nitrogen per hectare
B. Is in secondary plot that includes: variety including: Satina(early maturing) and Agria(late maturing).

By considering to soil propertises and according to the test which was done, in 0-30 centimeters depth of the soil, salinity of about 0.932 desyzimens/m, soil PH of 0.30, soil saturation percentage of 2sp, calcium carbonate of about 3.5 percent, organic carbon of 0.7 percent, total nitrogen of 0.07 percent, absorbable phosphorus of 11.33 ppm, absorbable potassium of 395 ppm, clay amount of 46.5 percent, silt amount of 27.5 percent, sand amount of 26 percent and clay soil texture was recorded. In order to measuring the traits, the sampling was done by destructive method with a regular timing of respectively 57, 70, 83, 94, 105and 116 days after sowing and a terminal recording was done, too.

The data recorded in eachsampling was tested by MSTAT software for each trait. If the primary data had a normal distribution, the data that are acquired by the sampling were analyzed as split plot design using this software. The variance analyses and means comparison of main effects and interactions were done as split-split-plot for samples that were collected during the time (which were rising). In this experiment, the factors N and V are nitrogen fertilizer and variety respectively and the factor S is the time (number of sampling). Mean comparisons of main effects and interactions were done by Duncan's multiple range tests with probability of 5 percent.

RESULTS AND DISCUSSION

Tuber yield per plant

According to results of variance analysis the factors that were studied including variety and nitrogen fertilizer and also the interaction of these two factors were significant in probability of 1 percent. Mean comparison in probability of 5 percent demonstrated that in main effect of variety, Agria variety was in the superior group and its tuber yield with 981.69gram per plant, was more than yield of Satina variety and also it's significant. Different experiments done (Carjady and Gaus, 1989), (Hossein et.al, 1995) and (Mollergan, 1993), indicate a significant interaction between potato varieties in different levels of nitrogen and different traits, specially yield. The most tuber yield per

plant is acquired with 160kg net nitrogen per hectare that in addition to having the highest value, was in the first group(a)and had a significant difference with other treatments. These results were reported by Sing and Sing(1994) and they expressed that the yield in fertilizer level of 180kg net nitrogen per hectare is 28.4 percent more than 60kg net nitrogen per hectare. 80 and 200kg net nitrogen per hectare fertilizer level s were in the same group together and there was not a significant statistical difference between them. The interaction of variety× nitrogen indicated that the most tuber yield was acquired for Agria variety with 160kg net nitrogen per hectare which had a significant difference with other treatments. Furthermore increasing fertilizer level from zero to 160kg net nitrogen per hectare had a significant positive effect on these traits in both varieties. But above this level a negative insignificant effect is resulted in both varieties. In variance analysis of this trait during the time, the factors including variety and tripartite interaction of variety ×nitrogen×sampling was significant in probability of 5 percent, also nitrogen factor, nitrogen ×variety interaction , sampling, and nitrogen×sampling interaction were significant in probability of 1 percent, but variety×sampling interaction showed no significant effect. Considering the mean comparison of the main effect of factors during the time, Agria variety showed significant difference and is in the superior group (by 552.60geram per plant). Furthermore, fertilizer levels of 80,160, and 200kg net nitrogen per hectare with significant difference compared to control were in the same and first group (a) together. But 160kg net nitrogen per hectare have had the most yield with 609.4 gram per plant and ultimately the most yield per hectare in final harvest was acquired in this fertilizer level.

Table1.Variance analysis of morphological traits of shoot in final recording

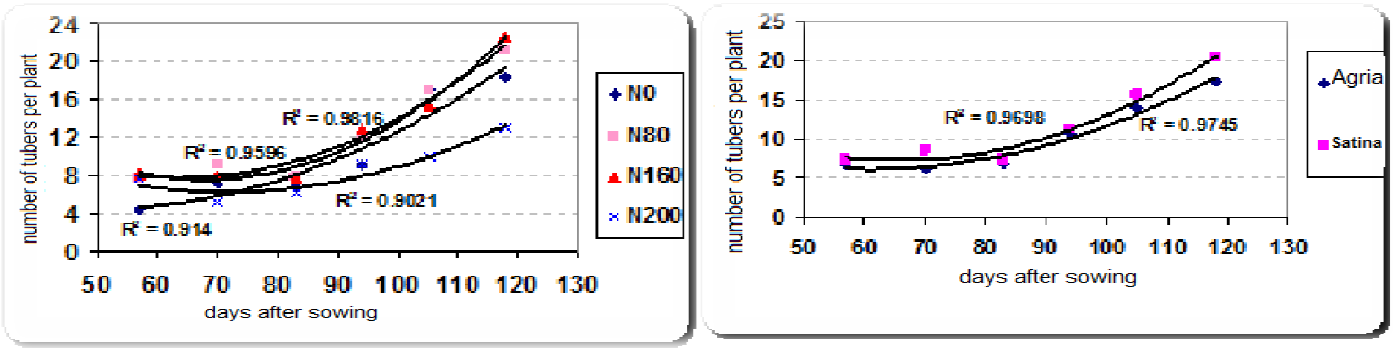
Variation sources	Degree of freedom	Tuber average weight	Mean Squares (MS)				
			Tuber yield per plant	Number of tubers per plant	Number of tubers smaller than mm28	Number of tubers in the size of 28-55Mm	Number of tubers larger than mm 55
Replication	3	80.120	9987.666	5.126	0.081	2.742	0.273
Nitrogen fertilizer(N)	3	3373.105**	324136.398**	22.388**	1.324*	15.737*	14.218**
Error	9	63.178	18402.634	2.529	0.215	2.403	0.709
)V(Variety	1	637.156**	132168.683 **	1.488 ns	1.240**	8.090**	0.813ns
V×interaction N	3	57.705*	59131.290 **	1.916ns	0.134**	0.382**	0.797ns
Error	12	13.902	6814.050	1.662	0.014	0.064	0.498
Coefficient of variation (%)	-	4.09	9.00	13.37	10.59	4.93	16.78

*Ns, * and ** are insignificant and significant in probability of 5 and 1 percent, respectively*

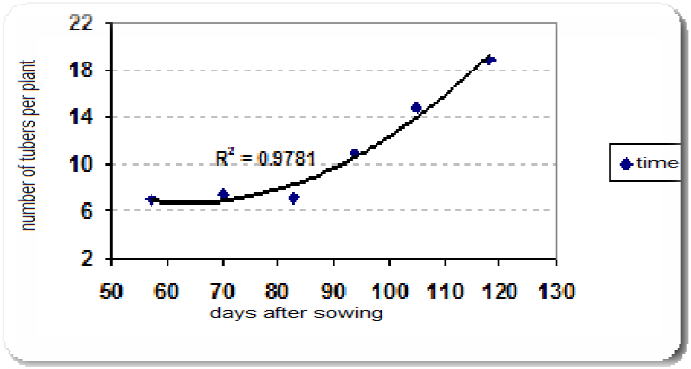
The control had the least effect on yield per plant and also per hectare which was significant. Considering the effect of nitrogen levels on the yield it can be concluded that increasing the amount of nitrogen causes an increase in the yield with a significant difference. But this yield increase occurs up to 80 kg net nitrogen per hectare fertilizer level and extraordinary use of nitrogen and in other word more than 80kg net nitrogen per hectare has no significant effect on increasing the yield per plant and the yield was almost the same. So increasing nitrogen fertilizer not only did not cause an increase in the yield but also results in a loss due to fertilizer buying, soil environment pollution and more nitrate accumulation. Studying the growth procedure(sampling) shows that tuber yield per plant increases significantly from the beginning of growing period and its highest value is acquired in last sampling(118days after sowing). The fourth and fifth samples were respectively in 94 and 105 days after sowing in the same group.

The mean comparisons of variety×nitrogen interactions during the time demonstrates that in Agria variety, fertilizer levels of 160 and 80kg net nitrogen per hectare has had a significant positive effect on these traits and they are placed in the same group. So that, by increasing fertilizer level up to 160kg net nitrogen per hectare in Agria variety the yield increases but by further increase of fertilizer(200kg net nitrogen per hectare) the yield not only doesn't increase but also decreases and has had a significant negativeeffect on this trait. This might be due to extra vegetative growth, putting some leaves in the shade and also, coincidence with high temperatures and long summer days and reduction of tuber reserves(the leaves that are in the shade become the consumers of assimilates instead of collecting them in tubers). The procedure of nitrogen level variation indicates that 160kg net nitrogen per hectare in the last sampling(118days after sowing) has had a significant statistical positive effect on tuber yield and was in superior group with 931.5 grams per plant. From the beginning of growth period to the end, in all fertilizer levels, tube yield per plant increases. Also the procedure of variety variation indicates that by increasing the length of growth period from the beginning to the end, tuber yield per plant increases significantly in both varieties. So that both varieties Agria and Satina are placed in superior group in the last sampling (118 days after sowing) and has had a significant positive effect on this trait. But in Agriavariety fifth and sixth sampling (105 and 118 days after sowing) are placed in the same and insignificant group.

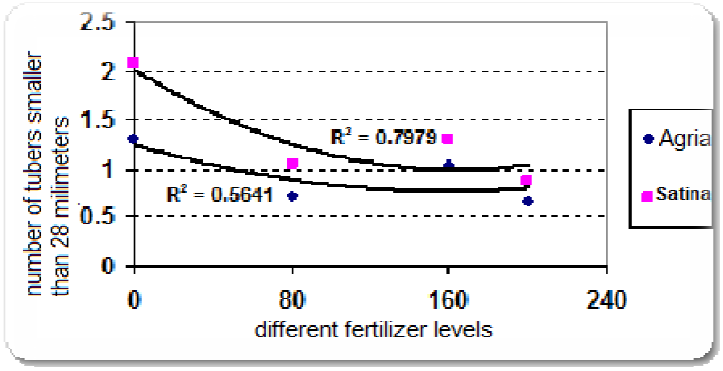
Figour1.Difference procedure of number of tubers per plant in different nitrogen levels(a) and studied varieties (b) during the time



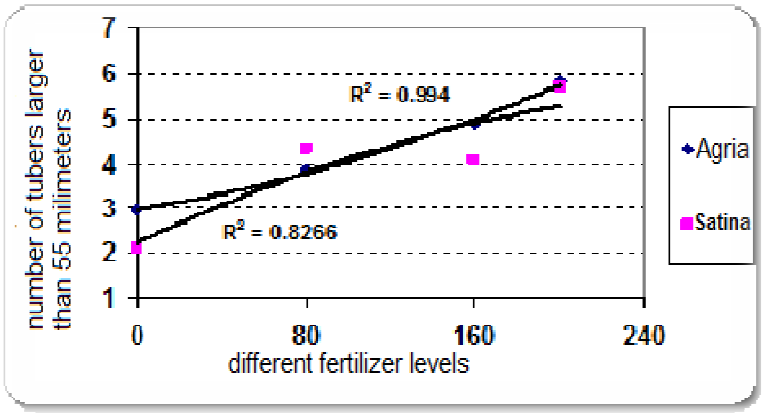
Figour2.Variation in average tuber numbers smaller than 28 millimeters in tested nitrogen fertilizer levels



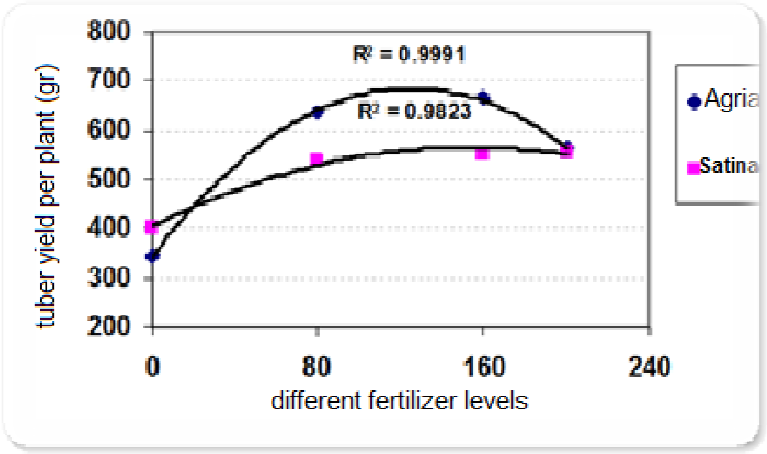
Figour3.Variation in average tuber numbers of 28-55 millimeters in tested nitrogen fertilizer levels



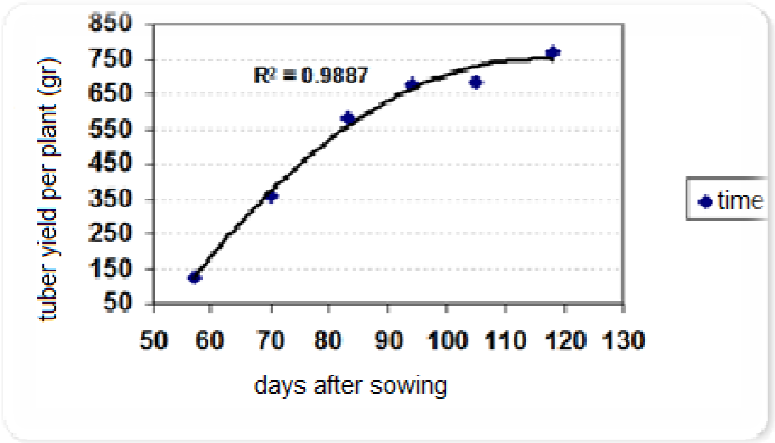
Figour4.Variation in average number of tubers larger than 55 millimeters in tested nitrogen fertilizer levels

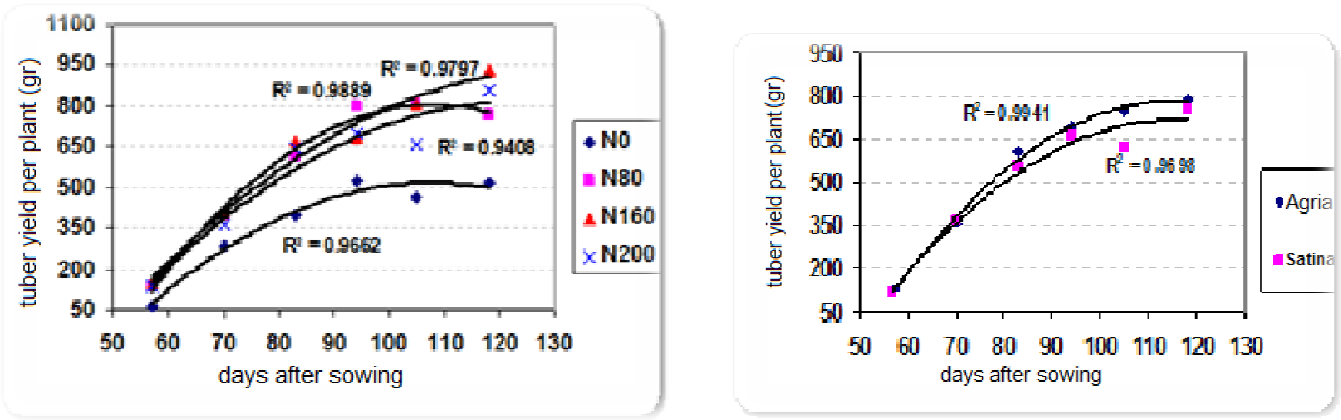


Figour5.Variation in average tuber yield per plant in tested traits during the time



Figour6.Variation of average tuber yield per plant during the time





(a) **(b)**

Figour7.Variation procedure of tuber yield per plant in different nitrogen levels (a) and the studied varieties (b) during the time

Tuber dry weight

By the variance analyses during the time, the main factors including variety, nitrogen, sampling and interactions ofnitrogen×variety and nitrogen×sampling had a significant effect in probability of 1 percent on this trait. Also interaction of variety×sampling and tripartite interaction of variety×nitrogen×sampling has had a significant effect on this trait in probability of 5 percent. The mean comparisons of main effect indicated that in the main effect of variety, Agria late maturing variety with 115.3 gram per plant is in superior group compared to Satina variety and has a significant positive effect on this trait. About the main effect of nitrogen the levels of 80, 160 and 200 kilogram net nitrogen per hectare has the best effect on tuber dry weight per plant and has a significant difference with control and were placed in the same superior group. The highest value for this trait was acquired in 160 kilograms net nitrogen per hectare with 121.9 grams per plant and the lowest value belongs to the control (zero kilogram net nitrogen per hectare) with 78.44 grams per plant. Number of samplings demonstrates that from the beginning of growth period to its end, tuber dry weight per plant increased significantly so that its highest value was acquired in 118 days after sowing with 162.7 gram per plant. But the 94 and 105 days after sowing (the fourth and fifth sampling) are in the same group. Procedure of variation in nitrogen levels was 80 kilogram net nitrogen fertilizer per hectare from the beginning of growth period to the fifth sampling. After this period 160 kilogram net nitrogen per hectare preceded them but totally these two levels and the 200 kilograms net nitrogen per hectare all were in the same group according to the main effect of nitrogen. The highest tuber dry weight in final sampling was in 160 kilograms net nitrogen per hectare with the value of 192.8 grams per plant. The procedure of variation among the varieties in this trait indicated that Agria variety was better than Satina during growth period from its beginning to the end, and the highest value of this trait acquired forAgria variety and 118 days after sowing with 169.9 grams per plant but it was in the same group with 94 and 105 days after sowing. In both varieties from the beginning of growing period to the end, the value of this trait increased significantly.

Table2. Variance analyses of morphological traits of plant during the time

Source of variation	Degree of freedom	Mean of squares	
		Number of tubers per plant	Tuber yield per plant (gr)
replication	3	13.527	4052.69
Nitrogen (n)	3	171.607 **	562754.79**
error	9	13.182	24100.83
Variety (v)	1	95.89/ **	77966.60 *
Interaction n×v	3	2.479ns	77451.23**
error	12	2.772	11795.02
Sampling (s)	5	763.638**	1923618.58**
Interaction n×s	15	28.318**	36429.46**
Interaction v×s	5	8.956ns	18029.72ns
n×v×s	15	5.379ns	26796.38*
error	120	6.668	12830.61
Coefficient of variation		23.49	21.27

*Ns, * and ** are insignificant and significant in probability of 5 and 1 percent, respectively*

Table3. Mean comparison of tested main effects on morphological traits of plant

	Tested levels	Mean of traits	
		Number of tubers per plant	Tuber yield per plant
varieties	Agria	10.29 b	552.60a
	Satina	11.70 a	512.29b
Nitrogen fertilizer	control	10.52 b	372.9b
	80 kilograms	12.51 a	587.4a
	160 kilograms	12.43 a	609.4a
	200 kilograms	8.52 c	560.2a
Sampling (days after sowing)	57 days	6.97 d	121.8e
	70 days	7.36 d	360.8d
	83 days	7.14 d	581.2c
	94 days	10.89 c	678.0b
	105 days	14.83 b	683.7b
	118 days	18.77 a	769.2a

The values with the same letters didn't show any significant effect in probability of 5 percent

Table4. Mean comparisons of variety×nitrogen, nitrogen×sampling, variety×sampling interactions on studied traits

Source of variation	Mean of traits	
	Number of tubers per plant	Tuber yield per plant (gr)
variety×nitrogen (kilograms per hectare)		
control×Agria	9.60c	344.6 c
control×Satina	11.43b	401.1c
Agria×80	12.08ab	636.9a
Satina×80	12.94a	537.8b
Agria×160	11.81b	665.9a
Satina×160	13.04a	552.8b
Agria×200	7.65d	563.0b
Satina×200	9.39c	557.5b
variety×sampling (days after sowing)		
Agria × 57	6.63ef	125.1 f
Agria× 70	6.19f	354.6 e
Agria × 83	6.94ef	609.1 cd
Agria× 94	10.63d	694.0bc
Agria× 105	14.06c	745.8ab
Agria × 118	17.28b	787.0 a
Satina × 57	7.32ef	118.5 f
Satina× 70	8.53 e	367.0 e
Satina× 83	7.35ef	553.2 d
Satina× 94	11.16d	662.0 c
Satina × 105	15.59bc	621.6 cd
Satina× 118	20.25 a	751.4ab

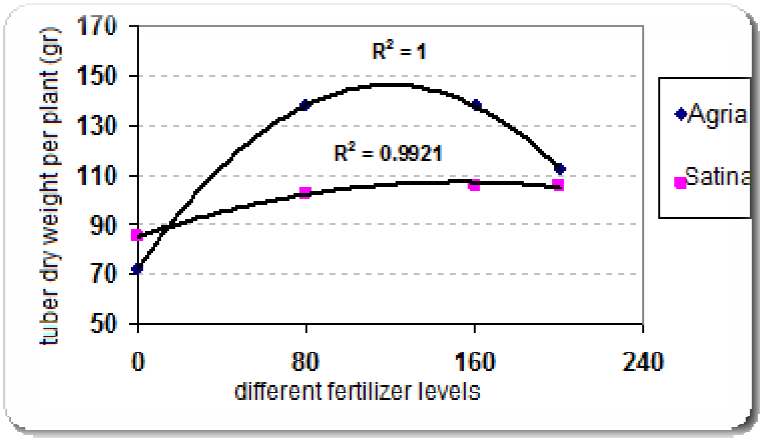
Remain of table 4

Source of variation	Mean of traits	
	Number of tubers per plant	Tuber yield per plant (gr)
Nitrogen (kilogram per hectare)× sampling (days after sowing)		
control × 57	4.32 j	61.69 l
control × 70	7.19g.j	268.3 k
control × 83	6.88hij	398.6ij
control × 94	9.25gh	526.2fgh
control × 105	17.06bc	463.8hij
control × 118	18.38 b	518.5ghi
57×80	7.69ghi	137.3 l
70×80	9.19gh	401.0ij
83×80	7.76ghi	612.8efg
94×80	12.25ef	800.6bc
80×105	16.94bc	807bc
118×80	21.25 a	765.5bcd
57×160	8.25gh	149.6 l
70×160	7.94ghi	410.5hij
83×160	7.75ghi	670.5 de
94×160	12.81 de	687.4cde
105×160	15.31 cd	807bc
118×160	22.50 a	931.2 a
57×200	7.60ghi	138.7 l
70×200	5.13ij	363.3jk
83×200	6.19hij	642.8def
94×200	9.25gh	697.8cde
105×200	10.00fg	657 de
118×200	12.94 de	861.6ab

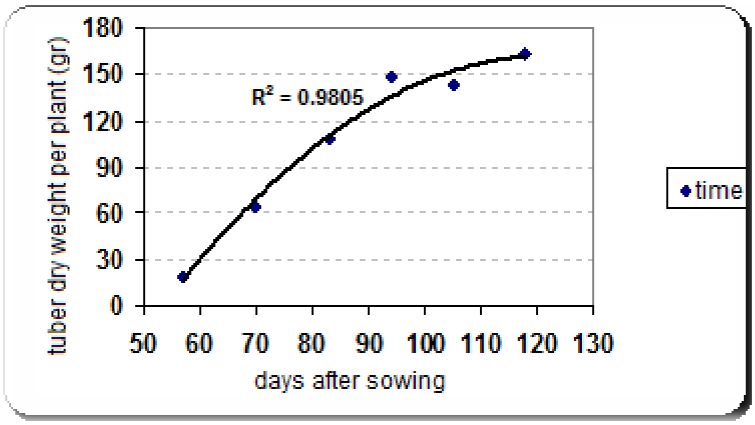
The values with the same letters didn't show any significant effect in probability of 5 percent

The interaction of variety×nitrogen during the time indicated that in Agria variety fertilizer levels of 160 and 80 kilogram net nitrogen per hectare had a significant positive effect on tuber dry weight with probability of 5 percent. So that these two levels was arranged in the same group. In Agria variety by increasing fertilizer level up to 160 kilograms net nitrogen per hectare the value of this trait increased, but above this level (200 kilograms net nitrogen per hectare) had a significant negative effect on tuber dry weight. In Satina variety by increasing fertilizer up to 80 kilograms net nitrogen per hectare the value of this trait increased significantly, but other levels of nitrogen (160 and 200 kilograms net nitrogen per hectare) are in the same group with 80 kilogram nitrogen per hectare. Foranz (1990) reported that the increase of tuber yield and tuber dry weight was significant by increasing fertilizer level from 80 to 120 kilograms net nitrogen per hectare and below this level the increase in yield and tuber dry weight was insignificant. By increasing fertilizer level from zero up to 100 kilogram net nitrogen per hectare tuber yield and tuber dry weight increased 2000 and 420 kilogram per hectare respectively. A three-year-long experiment on Diamont, Aola and Moren demonstrated that the best amount of nitrogen fertilizer used in order to increase dry matter is 80 kilograms net nitrogen per hectare. The use of nitrogen fertilizer can increase dry matter percentage to a limited extent (Maghrur, 1997).

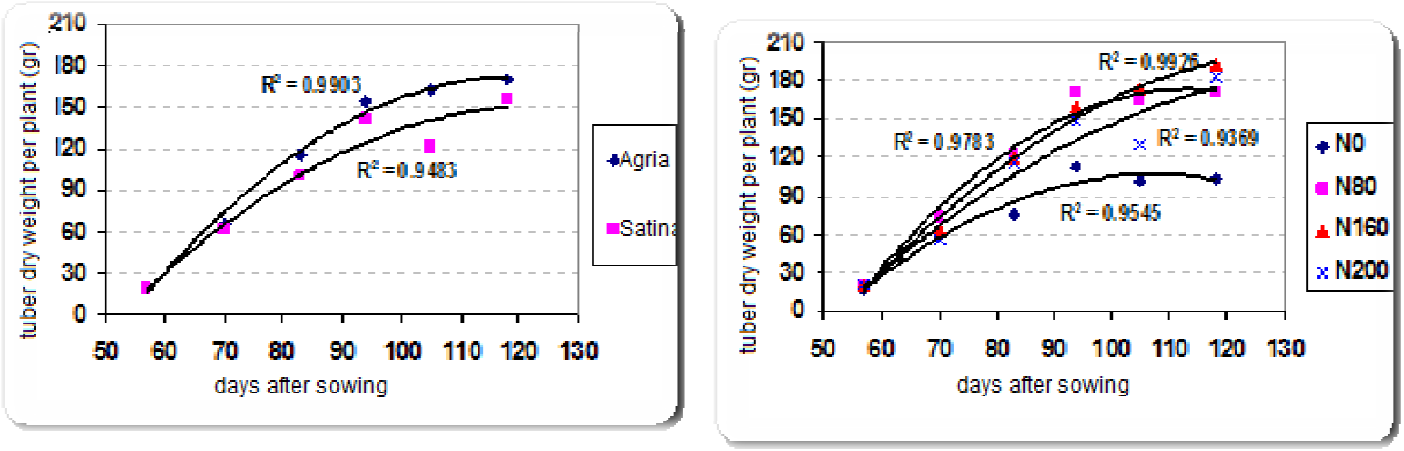
Figour8. Variation in average tuber dry weight per plant in tested nitrogen fertilizer traits during the time



Figour9. Variation in average tuber dry weight per plant during the time



Figour10. Variation procedure of tuber dry weight per plant in different fertilizer levels (a) and studied varieties (b)during the time



Tuber yield

The products that are supplied with high levels of nitrogen produce their maximum yield later than products that are faced with low nitrogen levels. Nitrogen promotes growth of shoots and although tuber forming in both high and low nitrogen levels may begin almost in the same time but in the beginning of growing period, there is less dry matter in tubers. It is proved that using high amounts of nitrogen and high intensity may cause the shoots to develop very much, delaying tuber formation, reducing the yield and forced harvest of raw tubers, and also may effect quality of tubers. Variance table represented that experimental factors and their interaction (variety×nitrogen) were significant in probability of 1 percent. The mean comparison of variety main effect shows the significant superiority of late maturing Agria compared to early maturing Satina. The studies on nitrogen levels stated that 160 kilograms net nitrogen per hectare fertilizer level is in superior group and has a significant difference with the control and the 80 kilograms net nitrogen per hectare, but were in the same group with 200 kilograms net nitrogen per hectare. Increasing fertilizer level up to 160 kilograms net nitrogen per hectare, the value of this trait increased significantly, but going beyond this level it doesn't have any significant effect on this trait. In other word the best fertilizer level in order to acquire maximum yield, is 160 kilogram net nitrogen per hectare. Increasing fertilizer level more than this amount, not only doesn't have any significant effect on increasing the tuber yield (tone per hectare) but also caused:

1-Extraordinary growth of shoots
2-More nitrate accumulation in the tuber which is a harmful trait for human
3-Pollution of soil and water environment
4-Increasing the costs by using more nitrogen fertilizer that is more than plant requirement.

Fertilizer level of 160 kilograms net nitrogen per hectare with a value of 34.53 tons per hectare is arranged in first group (a). Mean comparison table of nitrogen×variety interaction represents that the most tuber yield by 39.43 tons per hectare belongs to the treatment Agria×160 kilograms net nitrogen per hectare. This treatment has a significant difference with all the groups; also it is arranged in superior group. The least amount of this trait is acquired in control treatment of both varieties which are in the same group. In both varieties by increasing fertilizer level up to 160 kilograms net nitrogen per hectare (except Satina×160 treatment) the value of this trait increased and by increasing fertilizer level more than this level, the value for this trait decreased again. It shows superiority of Agria variety compared to Satina and Superiority of 160 kilograms net nitrogen per hectare fertilizer level compared to other nitrogen levels on this trait. By using no fertilizer the yield of Satina variety was more than Agria (their difference was about 3 tons per hectare) but by increasing fertilizer level,Agria variety preceded from Satina and in fertilizer level of 160 kilograms net nitrogen per hectare their difference was in the maximum amount. So it can be concluded that by considering the more growth period length of Agria variety, its need to fertilizer is more. It means Agria is more sensitive to nitrogen fertilizer. In low fertilizer level, Agria has feweryields and in 160 kilograms net nitrogen per hectare (optimum fertilizer level for this trait) it has the most tuber yield per hectare compared to Satina early maturing variety. But increasing fertilizer level above this amount decreased the yield in both varieties. Regarding this,Molergan (1990) reported that by increasing nitrogen levels in Bita variety, the yield increased whereas tuber yield increase for Danlo variety occurred in fertilizer levels more than 100 kilograms net nitrogen per hectare. Furthermore Piter and Arsenalt (1998) demonstrated that using nitrogen fertilizer increased total yield and economical yield of potato. In this experiment they concluded that by using 135 kilograms net nitrogen per hectare

the most tuber yield is acquired and in this level, the percentage of large tubers is in maximum amount and also tuber average weight is the highest value compared to other levels of fertilizer.

Nitrogen and protein

Table of variance analysis (table5) represents that the main effect of variety and nitrogen was significant in probability of 1 percent on traits including shoot and tuber nitrogen percentage, nitrogen uptake in shoots, tuber and whole plant, protein percentage and protein yield. The effect of interaction of variety and nitrogen fertilizer was significant on traits including tuber nitrogen percentage, nitrogen uptake in tubers and whole plant, protein percentage and protein yield. Mean comparison table (table6) represents that between two varieties, Satina variety is better than Agria because of its early maturity and its capacity for high amounts of nitrogen uptake, coinciding the traits including nitrogen percentage of tubers and shoots, nitrogen uptake in tubers, shoot and whole plant and protein percentage. Agria is in a better group than Satina only in the case of protein yield because of its high amount of dry matter production. In all the measured traits (tuber and shoot nitrogen percentage, nitrogen uptake in tubers, shoots and whole plant, protein percentage and protein yield) by increasing fertilizer level a significant difference is distinguished, so that in the treatment of using no fertilizer, all the traits are in the lowest level and in the use of 200 kilograms net nitrogen per hectare they are in the highest level.

Table 5. Analysis of variance of effect of N fertilizer level on N uptake and partitioning and protein content of potato cultivars

Sources of variation	df	Total shoot N content	Total tuber N content	Shoot absorbed N	Tuber absorbed N	Whole plant absorbed N	Tuber protein content (%)	Tuber protein yield
Replication	3	0.08*	0.29**	21.66*	27.01	3.71	11.64**	8451.5**
Cultivar (V)	1	0.24**	0.25**	160.52**	1150.6**	2170.7**	9.76**	25428.06**
Nitrogen (N)	3	1.29**	1.13**	975.07**	9898.78**	17059.4**	44.43**	33860.82**
V × N	3	0.03	0.08*	1.75	76.36*	78.93**	3.21*	1070.4*
Experimental error	23	0.01	0.01	4.46	17.27	12.08	0.63	288.03
C.V. (%)		5.18%	4.77%	7.36%	5.55%	3.36%	4.77%	4.25%

Table 6. Means comparison of effect of different N fertilizer levels on different traits of potato cultivars

Source of variations	Total shoot N content	Total tuber N content	Shoot absorbed N	Tuber absorbed N	Whole plant absorbed N	Tuber protein content (%)	Tuber protein yield
Cultivars							
Agria	2.47 b	2.57 b	26.10 b	67.84 b	93.95 b	16.10 b	431.18 a
Satina	2.67 a	2.78 a	31.28 a	81.69 a	112.97 a	17.38 a	366.08 b
N fertilizer levels							
0 kg/ha	1.99 d	2.15 d	15.29 d	30.75 d	46.04 d	13.47 d	317.55 d
80 kg/ha	2.43 c	2.49 c	21.90 c	52.52 c	74.42 c	15.59 c	361.63 c
160 kg/ha	2.85 b	2.95 b	33.39 b	95.21 b	128.60 b	18.43 b	425.93 b
200 kg/ha	3.03 a	3.11 a	44.18 a	120.58 a	164.76 a	19.45 a	489.41 a

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