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THE EFFECTS OF DIFFERENT NITROGEN DOSES ON TUBER YIELD AND SOME AGRONOMICAL TRAITS OF EARLY POTATOES

Leyla GULLUOGLU[1], H. Halis ARIOGLU[2], Halil BAKAL[2]

[1]Cukurova University, Vocational School of Ceyhan, Adana, TURKEY
[2]Cukurova University, Faculty of Agriculture, Department of Field Crops, Adana, TURKEY
[*]Corresponding author: gulluoglu@cu.edu.tr

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ABSTRACT

This study was conducted to determine the effects of different nitrogen rates on tuber yield and some agronomical traits of early potatoes grown in 2011 and 2012. The field trial was conducted at the experimental field of Cukurova University, in the Randomized Complete Block Designs, with three replications, with Marfona a medium early table potato. Zero, 40, 80, 120, 160, 200, 240, 280, 320 and 360 kg ha^{-1} pure nitrogen doses were applied. According to the mean values of two years, the total tuber yield was 24.0 ton ha^{-1} in the control plot. The highest yield per hectare (53.31 ton ha^{-1}) was obtained from the 240 kg ha^{-1} N applied plots. Beyond 240 kg ha^{-1} peak, as the dose was increased, the tuber yield was decreased. In addition, the marketable tuber yield ratio was 95.60 % with 0 N dose. When the N dose increased to 200 kg ha^{-1}, the marketable tuber yield has also increased up to 97.41. After 200 kg ha^{-1} dose, the marketable tuber yield has started to decrease.

Keywords: Early potato production, Nitrogen fertilizer, Potato, Tuber yield

INTRODUCTION

Potato an annual tuber crop with high adaptation to various climatic zones, is successfully cultivated almost in every part of the world as nutritional source (Arioglu, 2014).

Potato, which contains valuable nutrients such as carbohydrates in the form of starch, proteins, vitamins and iron (Fe) in its tubers, is consumed by humans directly as table potatoes and also as processed foods such as chips and French fries. In addition, its varieties that contain high levels of starch are utilized as raw materials in the production of flour, starch and alcohol, as well as animal feeding (Arioglu, 2014).

Due to its high nutritional value, potato could be considered one of the most important nutrients that could help to solve the starvation problem in the under-developed countries. Considering the starvation and malnutrition problems of millions of human beings, the Food and Agriculture Organization of the United Nations declared 2008 as the “International Year of the Potato” to promote awareness (Arioglu and Gulluoglu, 2014).

In the coastal regions of Turkey, where the Mediterranean type climate prevails with warm winters, potato is produced as early as possible with high tuber yield (Arioglu and Caliskan, 1999; Arioglu et al., 2002). The total potato production of Turkey in 2013 was 4.8 million tons; 300,000 tons of which were cultivated as the early potatoes (Anonymous, 2013).

The potato plant takes up substantial amounts of plant nutritional elements from the soil during the growing period. It stores approximately 1/2 to 1/3 of the plant nutritional elements in its vegetative parts. The remaining plant nutritional elements are stored in the tuber (Mikkelsen, 2006; Arioglu, 2014).

It was reported that when 3 tons of potato tubers are harvested per hectare, l50 kg of N, 60 kg of P_2O_5, 350 kg of K_2O, 90 kg of CaO and 30 kg of MgO per hectare are taken from the soil by the plants (Beukema and Van Der Zaag, 1979).

Potato plants require nitrogen fertilizers substantially. Studies conducted in the Erzurum province of Turkey by Karadogan (1996) and Ozturk et al. (2007) indicated that as the doses of nitrogen were increased, tuber yields were also increased. Since potatoes are produced in sandy soils and require substantial amounts of irrigation, the soil is subject to serious nitrogen leaching. Depending on the purpose of cultivation, it is vital that the nitrogen fertilizers should be applied to fields to compensate losses in the potato cultivation. Substantial amounts of nitrogen fertilizers applied at the early stages stimulate the development of vegetative parts with delay in tuber initiation ((Mikkelsen, 2006). So, this type effect of nitrogen fertilizers should be considered in the early potato production (Ozer ve Arıoglu, 1994; Arioglu, 2014).

In order to regulate tuber initiation and to prevent nitrogen leaching, the application of nitrogen fertilizers at two different times was suggested, such as the application of ½ of the fertilizer at the time of planting, and half of the remaining ½ at the time of the hilling (5 to 6 weeks after the plants emerge from the soil surface) and the rest when the tubers reach the size of an egg, increases tuber yield (Rosen and Bierman, 2008; Davis et al., 2014). The leaching of nitrogen should be considered in sandy soils so the amount of nitrogen fertilizers applied should be increased and the fertilizer should be applied by the sprinkler irrigation at several times (Yilmaz, 1992; Hochmuth and Hanlon, 2014).

The amount of nitrogen fertilizers to be used in potato cultivation should be based on the target crop quantity and the type of the soil, since potato plants require a certain amount of nitrogen intake from the soil for certain tuber yield levels. When aiming for certain levels of tuber yield from potato crop, the properties of the variety and the suitability of the environmental factors should also be considered (Rosen, 2013; Arioglu, 2014). The results of research conducted for main crop in the various regions suggested the application of 100 to 210 kg ha^{-1} nitrogen fertilizers as the proper amount in order to reach high quality and quantity tuber yield per unite area in Turkey (Taskiran and Esendal, 1988; Kasap, 1994; Tuncturk et al., 2004). Previous research showed that the quantity of nitrogen fertilizers that should be applied in potato cultivation changes from region to region. But we do not yet have the results of early potatoes in the region. Therefore the purpose of this study was to investigate the optimal nitrogen fertilizer rate and its timing to obtain economic yield in the early potato production in the Cukurova region.

MATERIALS AND METHODS

Research Materials

The study was conducted at the Research Fields of the Cukurova University, Faculty of Agriculture (Southern Turkey, 36°59' N, 35°18' E; 23 elevation). The design of the field trial was the Randomized Complete Block with 3 replications, in 2011 and 2012 years. Marfona, a medium early potato variety, was used as a plant material. Potassium Sulfate (50% K_2O), Triple Superphosphate (42-44% P_2O_5), Ammonium Sulfate (21% N) and Ammonium Nitrate (33% N) were used as chemical fertilizers.

Soil Properties of the Research Area

The soil of the experimental field had a loamy structure with pH levels of 7.28-7.29. The salt content of the soil was 0.052 % to 0.060 %. The usable P_2O_5 content was 14.17 % at the upper layers with the content decreasing in the lower layers. In addition, the nitrogen content of the soil was 0.122 % at the upper layers and 0.056 % at the lower layers. The lime content was 33.02 % at the upper layers with the increased levels in lower layers.

Climate of the Research Area

In the Adana province of Turkey, winters are mild and rainy, whereas summers are dry and warm, which is a typical of a Mediterranean climate. The average monthly temperatures during the research period were 16.7 to 28.9 °C in 2011, whereas it was in the 18.8 to 29.4 °C interval in 2012. The maximum temperature for Adana was 39.3 °C in 2011 and was 40.6 °C in 2012. The total precipitation was 184.7 mm and 110.4 mm in 2011 and 2012, respectively (Turkish State Meteorological Service Adana Regional Directorship, 2011 and 2012).

Planting and Management

The field was cultivated deeply by the moldboard following the harvest of the previous crop in the fall, and then the soil was prepared by using diskharrow. The plantings were done by hand in the second week of January in two years, with 70 cm between row distance and 30 cm in-row distance. The plot size was set as 14 m^2 (2.8 m x 5.0 m). Before planting, 550 g Triple Superphosphate (42-44% P_2O_5) and 450 g Potassium Sulfate (50% K_2O) fertilizers per plot were applied to the furrows by hand and afterwards seed tubers were placed in the furrows according to the given row spaces.

During the growing period, Ridomil was applied three times to prevent late blight (*Phytophtora İnfestans*) and overhead sprinkler irrigation was applied two times. During the growing period, other standard cultural practices were applied at proper time intervals. The planned Nitrogen application doses and times are given in Table 1.

Table 1. The Application of Nitrogen Doses and Times

Treatment Number	Nitrogen Doses (Kg ha^{-1})	Nitrogen Application Time and Doses		
		Planting	Tuber initiation*	Tuber bulking**
1	0	0	0	0
2	40	40	0	0
3	80	40	40	0
4	120	60	60	0
5	160	80	80	0
6	200	100	100	0
7	240	80	80	80
8	280	100	100	80
9	320	110	110	100
10	360	120	120	120

* 5th of April 2011; **25th of April 2012

Measurement of characteristics

The tubers were harvested in the first week of June. The plants in the middle two rows of each plot were harvested by hand. The number of tubers plant^{-1}, tuber yield plant^{-1}, marketable tuber yield ratio (tubers in 25 mm), dry matter content and tuber yield hectare^{-1} were determined following the harvest (Onaran and Arioglu, 1999). The standard analysis of variance was used to analyze the traits measurement. The Least Significant Differences (LSD) test was used to comparing the treatments at 0.05 level (Steel and Torrie, 1980).

RESULTS AND DISCUSSIONS

Tuber Yield and Marketable Tuber Yield

The total tuber yield per hectare and the percentage of marketable tuber yield values are presented in Table 2.

Table 2. The Effect of Different Nitrogen Doses on Total Tuber Yield (ton ha^{-1}) and the Percentage of Marketable Tuber Yield (%) in the Early Potato Production at Adana-Turkey.

N Dose (kg ha^{-1})	2011		2012		Mean	
	TTY* (ton ha^{-1})	PMTY** (%)	TTY* (ton ha^{-1})	PMTY** (%)	TTY* (ton ha^{-1})	PMTY** (%)
0	20.76	95.6	27.53	95.6	24.06	95.6
40	31.98	96.8	34.38	95.9	33.18	96.3
80	36.68	97.1	48.66	96.0	42.67	96.6
120	38.80	97.1	51.98	96.6	45.39	96.8
160	41.24	97.5	54.81	97.0	48.03	97.2
200	43.53	97.7	54.44	97.1	48.98	97.4
240	45.93	97.6	**60.68**	96.4	**53.31**	97.0
280	**46.63**	96.7	54.71	96.4	50.67	96.6
320	44.50	96.4	53.14	96.4	48.82	96.4
360	42.70	96.3	52.74	96.3	47.72	96.3
Average	39.28	-	49.31	-	44.29	-
LSD(5%)	6812	0.94	4162	0.68	12180	0.56

* TTY: Total tuber yield; ** PMTY**:** The percentage of marketable tuber yield

Table 2 shows that the lowest tuber yields were observed when non nitrogen fertilizer was applied during the planting and the growing period, in both years. As the amount of nitrogen fertilizers applied was increased, tuber yield hectare^{-1} also increased substantially. The highest tuber yields hectare^{-1} were obtained from the plots where 280 kg ha^{-1} (with 46.63 ton ha^{-1} yield) nitrogen was applied in 2011, and 240 kg ha^{-1} (with 60.68 ton ha^{-1} yield) nitrogen was applied in 2012. This increase has continued up to 280 kg ha^{-1} nitrogen application in 2011 and 240 kg ha^{-1} nitrogen application in 2012. Besides high nitrogen levels resulted in decreases in tuber yield. In addition, the tuber yield levels in 2012 were higher when compared to those in 2011. This could be due to the negatively affected vegetative growth of the plant as a result of low temperatures in 2011. Also, the seed tubers utilized in 2012 were comparatively bigger than those used in 2011. The highest tuber yield, based on the average values for both years, was observed in the plots where 240 kg ha^{-1} of nitrogen fertilizer were applied, resulting in a total yield of 53.31 ton ha^{-1}. Based on the average values for both years, it was observed that as the nitrogen fertilizers applied was increased, the tuber yield was also increased. This increase has continued up to 240 kg ha^{-1} nitrogen application followed by a decrease in yield beyond that amount (Fig. 1).

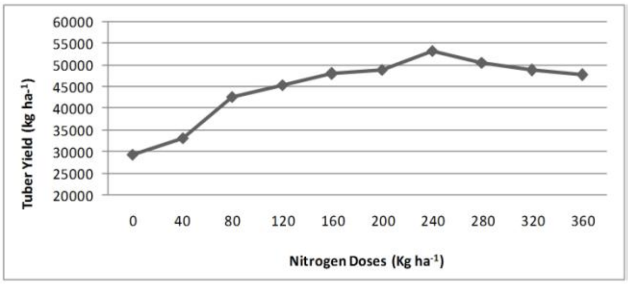

Figure 1. The Effect of Nitrogen Doses on Total Tuber Yield of Early Potato Growing at Adana-Turkey

This decrease could be explained as follows. The additional nitrogen stimulated the development of the vegetative growth of the plants. However, the vegetative parts of the plants did not utilize light energy sufficiently. But, the vegetative parts continued to respire, leading to a substantial amount of dry mater that resulted from photosynthesis to be consumed as a result of respiration. Consequently, the tuber yields were decreased. These findings are supported by Ozer ve Arıoglu (1994), Karadogan (1996) and Ozturk et al. (2007).

In potato growing, the marketable tuber yield is an important trait. The highest marketable tuber yield percentage (97.4%) was obtained in the plots where 200 kg ha^{-1} nitrogen fertilizer was applied. In 2011, this figure was 97.7%, whereas in 2012, it was 97.1% (Table 2). Similar results were reported by other researchers (Taskiran and Esendal, 1988; Kasap, 1994; Tuncturk et al., 2004; Rosen and Bierman, 2008; Rosen, 2013).

Tuber Number and Tuber yield per Plant

The number of tubers and tuber yield of per plant are presented in Table 3.

Table 3. The Effect of Different Nitrogen Doses on the Number of Tubers and the Yield per Plant in the Early Potato Production at Adana-Turkey.

N doses (Kg ha^{-1})	Year				Mean	
	2011		2012			
	TN*	TY**	TN*	TY**	TN*	TY**
0	4.7	358.3	7.3	590.7	6.0	474.5
40	5.9	559.7	8.5	778.0	7.2	668.8
80	6.6	642.0	10.0	1125.0	8.3	883.3
120	6.8	679.3	10.7	1240.0	8.8	959,8
160	7.1	722.0	10.8	1270.0	9.0	996.2
200	7.4	761.7	10.8	1306.0	9.1	1034.0
240	7.8	804.0	10.9	1329.0	9.4	1066.0
280	7.6	816.0	11.2	1337.0	9.4	1077.0
320	7.4	779.0	11.5	1396.0	9.4	1037.0
360	7.0	747.3	11.5	1279.0	9.2	1013.0
Average	6.83	686.9	10.32	1165.1	8.58	920.96
LSD(%5)	1.15	119.0	1.98	189.8	1.11	108.1

* TN: Tuber number per plant (number plant^{-1})
** TY: Tuber yield per plant (g plant^{-1})

Table 3 shows that tuber number per plant in 2011 was in the range of 4.7 (control) to 7.8 (240 kg ha^{-1}) number plant^{-1}, and 7.3 (control) to 11.5 (320 kg ha^{-1}) number plant^{-1} in 2012. The number of tubers per plant in 2011 increased up to 240 kg ha^{-1} nitrogen fertilizer application, followed by decreases beyond that point. On the other hand, in 2012, as the amount of nitrogen fertilizer increased, tubers per plant increased as well. The reason for discrepancy between years could be the plants being affected by low temperatures in 2011 and the large seed tubers developed more main stem in 2012 (Arioglu, 2014). Based on the average of two years, the highest number of tubers per plant was obtained by 240 kg ha^{-1} nitrogen fertilizer was applied (9.4 number plant^{-1}). As the amount of nitrogen fertilizers applied increased, the number of tubers per plant also increased, as well (Ozer and Arıoglu, 1994).

Means of plant yields in 2011 were 358.3 to 816.0 g plant^{-1}. In 2011, the highest yield was obtained in the plots, where 280 kg ha^{-1} nitrogen fertilizer was applied. On the other hand, the tuber yield means for 2012 was ranged between 590.7 and 1396.0 g plant^{-1}, compared to the means in 2011. In 2012, the highest yield was obtained in the plot, where 320 kg ha^{-1} nitrogen fertilizer was applied. The mean of 2012 were higher than those obtained in 2011. This difference could be due to low temperatures occurred in 2011. Beside large seed tubers might develop high vegetative growth, leading to increased yields. Based on the means of both years, the highest tuber yield per plant was obtained from 280 kg ha^{-1} nitrogen fertilizer. The tuber yields in the control plots were 474.5 g plant^{-1}, whereas it was 1077 g plant^{-1} in plots, where 280 kg ha^{-1} nitrogen fertilizer was applied. Beyond certain rates of nitrogen fertilizer applications, the tuber yield per plant started to decrease due to the excessive amounts of vegetative parts are not affecting photosynthesis positively in April and May in the Cukurova Region. These findings were in agreement with the findings of Ozer and Arıoglu, (994), Karadogan (1996), and Ozturk et al. (2007).

Dry Matter Content

Dry matter content is presented in Table 4. Table 4 shows that as amount of the nitrogen increased, the dry matter content in the tubers decreased in two years. The values for 2011 were between 15.63% (360 kg ha^{-1}) and 18.63% (40 kg ha^{-1}).

Table 4. The Effect of Different Nitrogen Doses on the Dry Matter Content (%) of Tubers in the Early Potato Production at Adana-Turkey.

N rate (kg ha^{-1})	Year		Mean
	2011	2012	
0	17.52	16.52	17.02
40	18.63	17.77	18.20
80	18.20	17.63	17.92
120	17.90	17.38	17.64
160	16.85	16.24	16.55
200	16.80	16.15	16.48
240	16.15	15.88	16.02
280	15.90	15.23	15.57
320	15.88	15.23	15.56
360	15.63	15.27	15.45
LSD (5%)	0.82	0.79	0.87

The highest dry matter content (18.63%) was observed from the treatment 40 kg ha^{-1} nitrogen application at planting time. As the amount of nitrogen fertilizer increased up to 360 kg ha^{-1}, the dry matter content was decreased down to 15.63%. Similar results were also obtained in 2012. The dry matter content decreased from 17.77% levels to 15.23% levels. When the results for both years are compared, it could be observed that the dry matter content was higher in 2011. The reason for this difference might be large tubers. As the tuber size gets larger, the dry matter content in the tubers starts to decreases.

The means for both years indicated that as the nitrogen rate increased, the dry matter content decreased. In the plots, where 360 kg ha^{-1} nitrogen fertilizers were applied, the dry matter content in the tubers was 15.45%, whereas it was 18.20% in the plots, where 40 kg ha^{-1} nitrogen fertilizer was applied (table 3). As the amount of nitrogen fertilizers applied increased, the tubers get bigger and consequently, the dry matter content per tuber decreased, while water content increased. Therefore, in processing type potato cultivation, substantial amounts of nitrogen fertilizers should not be applied. These findings are supported by the findings of Mikkelsen (2006).

CONCLUSIONS

The results and their discussions show that the application type and amount of nitrogen fertilizers at different doses and periods resulted in substantial increases in yield. As the rates of nitrogen fertilizer applications increased, tuber yields were also increased, leading to some increases in net income. The optimal and most economical nitrogen fertilizer application level was 240 kg ha^{-1}, resulting in the highest net income and net income increase levels. Based on the results of the study, it could be suggested that 1/3 of the fertilizer could be applied during the planting, 1/3 applied during the tuber initiation, and the remaining 1/3 during the period where the tubers reach the size of an egg.

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