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Influence of Nitrogen Levels on Productivity of Potato (*Solanum tuberosum* L.) Cultivars

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Abstract— *The experiment was established to define the response of two potato cultivars (Marabel and Madeleine) to four different nitrogen levels (N_0, N_{90}, N_{180} and N_{270} kg ha^{-1}) in 2020 growing season. It was determined that the significant differences between the potato cultivars for number of tubers per plant, tuber yield and dry matter content. Marabel cultivar gave the highest number of tubers (5.62 no. plant^{-1}), tuber yield (122.90 kg ha^{-1}) and dray matter (% 21.85). All the investigated characteristics (number of tubers per plant, average tuber weight, tuber yield, dry matter, canopy temperature, leaf chlorophyll content and leaf area index) were significantly affected by nitrogen levels. With increasing nitrogen levels, leaf chlorophyll content and leaf area index were increased but plant canopy temperature was decreased. N_{180} treatment gave the highest tuber yield (142.93 kg ha^{-1}) and dry matter (% 25.44).*

Keywords— *Leaf area index, nitrogen doses, potato cultivar, tuber yield.*

I. INTRODUCTİON

Potato, which is among the most consumed food products in the World, is one of the major crops contributing to food security on a global scale with its superior yield (Devaux *et al.,* 2014). Therefore, sustainable potato production in different ecologies is essential for food security and combating malnutrition. Potato occupies an important place among the food crops with it is annual production of 370 million tons on area of 17.3 million hectares in the world (Anonymous, 2019). Fifty-five percent of the world's potato cultivation areas are in China, India, Russia and Ukraine, and these four countries constitute 50% of the world potato production. Turkey is a country with favorable conditions for the potato cultivation. In Turkey, potato production are made in area of 140 766 hectares annually and 4.9 million tons of potato are produced from that area (Anonymous, 2019).

Fertilization, especially nitrogen fertilizer, has an important share in potato production inputs. Nitrogen fertilization has remarkable effects on growth and yield of potato plant (Villa *et al.,* 2017). Nitrogen, which promotes the formation of stems and leaves in the plant, is a nutrient that directly affects the important physiological functions in the plant, and amount and quality of product. It is the main ingredient of protein in plants and is the basic structure of chlorophyll, which converts solar energy into useful energy for the plant. Nitrogen plays a determinative role in potato plant development and tuber yield (Gastal and Lemaire, 2002; Lemaire et al., 2008). Nitrogen is the most emphasized nutrient in potato cultivation, and tuber yield and quality are negatively affected by its deficiency or excess (Echeverría, 2005; Caldiz, 2006; Samborski *et al.,* 2009). The potato plant removes approximately 120-140 kg ha^{-1} N in order to produce 25-30 tons of tubers from a hectare area (Patel and Patel, 2001). Dry matter ratio of potato tubers increases with nitrogen application (Sharifi *et al.,* 2007; Neshev *et al.,* 2014). Nitrogen application has a considerable impact on the leaf area index (LAI) by increasing the leaf number and leaf width of the potato plant (Vos and Biemond 1992, Vos and Van der Putten 1998). The effect of nitrogen on LAI is that it increases the efficiency by increasing the use of light and photosynthetic activity (Evans and Terashima 1988; Evans 1989; Geremew *et al.,* 2007; Sadras and Lemaire, 2014; Fischer *et al.,* 2016).

Nitrogen can be lost by precipitation and irrigation in very permeable soils and sandy-loom soils. Using too much nitrogen in potato production has enormous disadvantages in terms of environment and economy. Therefore, taking into account the soil and irrigation conditions, it is necessary to give nitrogen in an amount that can provide the targeted yield and meet the needs of the plant. This research was set up to determine the effect of different nitrogen doses on productivity of two edible potato varieties.

II. MATERİALS AND METHODS

Experimental Site and Conditions

Field study was conducted in Kahramanmaras city, which is located in the Eastern Mediterranean region of Turkey (between 37º 36' north parallel and 46º 56' east meridians). The climate in this area is Mediterranean, with hot and dry summers and rainy winters. The study area had monthly air temperature between 15.9 and 30.5 °C. Annually total precipitation is average about 487.6 mm but the total precipitation of during the potato crop season is about 85 mm. Soil had a loam-clay texture, 1.49% low organic matter, available phosphorous (9.86 mg kg^{-1}) and potassium (213 mg kg^{-1}) and pH of 7.6 slightly alkaline.

Experimental Material, Design and Cultural Practices

The medium-early potato cultivars "Marabel" and "Madeleine" were planted with a planting density of 2.88 plants per m^2 in the fourth week of April and treated with four

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N levels [0 (N_0), 90 (N_{90}), 180 (N_{180}) and 270 (N_{270}) kg ha^{-1}] in randomized block design with 3 replications. Nitrogen at the specified rates was applied in two splits in the form of urea (1/2th at planting and 1/2th at about 30 days after emergence). After emergence, plants were hoed 3 times by hand. Drip irrigation was carried out when the accumulated daily evaporation reached 40 mm and supplying 100% of maximum evapotranspiration. The harvest area consisted of 20 plants from the center of each plot. Plants were harvested by hand at the beginning of September.

Data Collection

The number of tubers was determined by counting of tubers from 20 plants in the middle two rows of each plot and averaged. Tuber weight was determined by weighing the total tubers of 20 plants from the center 2 rows of each plot (Gebremariam *et al.*, 2016). Tuber yield was determined for each treatment plot at crop maturity. The harvested potato tubers in the middle two rows of each plot were weighted and tuber yield (kg ha^{-1}) was calculated (Gebremariam *et al.*, 2016). Tuber samples were cut into small pieces and dried at 70 °C until a constant weight was reached and dry matter (%) was determined (Calıskan *et al.*, 2004).

Chlorophyll content was measured in the field using a portable chlorophyll meter (SPAD 502, Minolta Co. Tokyo, Japan). Measurements were performed between 10 and 14 hours on the 10 July 2020. Triplicate readings were taken at each leaf of the five plants and the average value was taken as the chlorophyll content (Mauromicale *et al.*, 2006). Plant canopy temperature was determined using a hand-held infrared thermometer in the middle of the day. The plant temperature was measured on three plants from four directions (east, west, north, and south) at 0.50 m from the crop, and then averaged (Stark et al., 1991). Leaf area was measured from randomly selected three plants in each plot on 10 July 2020. Leaves were separated from the stem and the surface areas of all leaves were measured by optical Area Meter. Leaf area index (LAI) was calculated following the standard formula (Jahan *et al.*, 2014) as mentioned below:

$$\text{Leaf area index (LAI)} = \text{Leaf area (cm}^2\text{)} / \text{Ground area (cm}^2\text{)}$$

Statistical Analyses

Data from the study were analyzed using the MSTAT-C statistical programming. The significant of the difference between means was compared by least significant difference test (Protected LSD, P < 0.05).

III. RESULTS AND DISCUSSION

The results of the analysis of variance of investigated parameters are shown in Table 1. It could be seen in Table 1, number of tubers, tuber yield and dry matter for cultivars, all investigated parameters for nitrogen levels, and canopy temperature, tuber weight, tuber yield and dry matter for cultivar x nitrogen interactions (C x N) were statistically significant.

TABLE I. Effects of different nitrogen levels on canopy temperature, leaf chlorophyll content, leaf area index, number of tubers, tuber weight, tuber yield and dry matter of potato cultivars.

	Canopy temperature (°C)	Leaf chlorophyll content (SPAD)	Leaf area index (LAI)	Number of tubers / plant	Average tuber weight (g)	Tuber yield (kg ha^{-1})	Dry matter (%)
Cultivars (C)							
Marabel	37.64	33.15	1.58	5.62 a	61.57	122.90 a	21.85 a
Madeleine	38.36	30.99	1.59	4.97 b	60.77	109.08 b	20.70 b
LSD $_{0.05}$	ns	ns	ns	0.38	ns	6.47	0.95
Nitrogen (N)							
0 (N_0)	38.59 ab	26.70 b	1.28 c	4.58 b	62.58 b	98.73 b	19.32 b
90 (N_{90})	39.42 a	30.12 b	1.57 b	6.10 a	66.05 ab	139.14 a	20.24 b
180 (N_{180})	36.88 b	35.83 a	1.65 b	5.83 a	68.53 a	142.93 a	25.44 a
270 (N_{270})	37.11 b	35.63 a	1.83 a	4.67 b	47.53 c	83.18 c	20.07 b
LSD $_{0.05}$	1.91	5.22	0.13	0.53	4.22	9.16	1.35
Analysis of variance for traits							
C	3.09	27.95	0.01	2.47**	3.8	1147.2**	7.95*
N	7.21*	119.02**	0.31**	3.68**	531.9**	5272.9**	47.30**
C x N	11.94*	11.80	0.01	0.47	156.4**	212.4*	6.19**

*, ** significant at the 0.05 and 0.01 level, respectively; for each trait, values within columns followed by the same letter are not significantly at P=0.05; ns, non-significant.

Number of tubers per plant, tuber yield and dry matter were higher for potato cultivar Marabel than for potato cultivar Madeleine. There were no significant differences between the potato cultivars with regard to canopy temperature, leaf chlorophyll content, LAI and average tuber weight. The higher tuber yield of the Marabel variety is due to the higher number of tubers per plant. The relationships between yield and yield components in potato has been studied by some researchers (Özkaynak *et al.*, 2003; Arslan, 2007; Khayatnezhad *et al.*, 2011; Zabihi-e-Mahmoodabad *et al.*, 2011; Singh *et al.*, 2015). They reported that stronger positive and substantial correlations were found between tuber yield and number of tubers per plant.

All studied characters were significantly affected by nitrogen levels (Table 1). N treatments significantly increased leaf chlorophyll content, LAI, number of tubers, tuber yield and dry matter except canopy temperature. N_0 and N_{90} levels produced the highest canopy temperature. When nitrogen was increased from N_{90} to N_{180}, the canopy temperature was reduced approximately 6%. The cultivars x nitrogen levels interaction was significant for canopy temperature (Fig. 1). The canopy temperature increases at low N levels can be

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explained by nitrogen deficiency. The high canopy temperature due to nitrogen deficiency was higher for Medelaine cultivar. Blad *et al.* (1988) reported that N fertilization had an important effect on the canopy temperature of wheat plant. In addition, Coast *et al.* (2020) working with cotton, also founded that plants treated with high N under well-irrigated condition had a cooler canopy than the nitrogen free plants. With increasing N levels, leaf chlorophyll content and LAI significantly tended to increase (Table 1). Although N_{180} and N_{270} treatments produced the highest leaf chlorophyll content, the N_{270} treatment gave the highest LAI. Villa et al. (2017) reported that N treatment was considerable increased leaf chlorophyll content and LAI. Similar observations were made by Mauromicale *et al.* (2006), Giletto *et al.* (2010), Kundu *et al.* (2019), who stated that increased nitrogen level resulted in a prominent increase in LAI and leaf chlorophyll content.

Nitrogen applications significantly increased number of tubers, average tuber weight, tuber yield and dry matter (Table 1). Some experiments for diverse ecologies have demonstrated that nitrogen effects yield and yield components of potato crop (Gezgin ve Uyanöz, 1998; Gebermarin *et al.*, 2016; Akpınar *et al.*, 2019; Kundu *et al.*, 2019; Coast *et al.*, 2020). N_{180} treatment produced the highest number of tubers, average tuber weight, tuber yield and dry matter. When nitrogen was increased from N_{180} to N_{270}, the number of tubers, average tuber weight, tuber yield and dry matter were reduced approximately 20%, 30%, 42% and 21% respectively. The minimum values were generally recorded in N_0 treatment. The cultivar x nitrogen level interactions were significant for average tuber weight, tuber yield and dry matter (Fig. 2, 3 and 4).

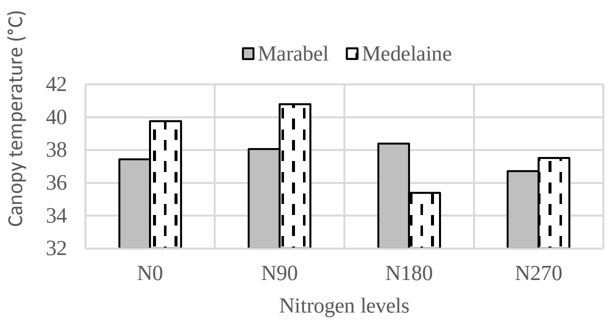

Fig. 1. Influence of potato cultivars x nitrogen levels interaction on canopy temperature.

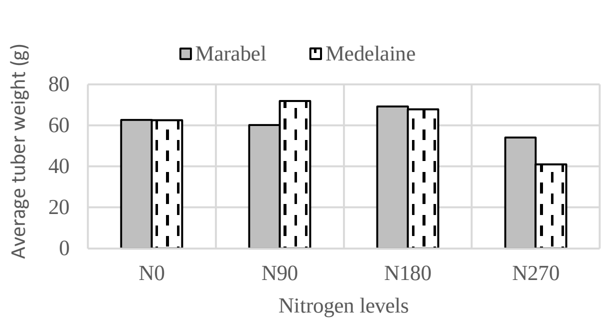

Fig. 2. Influence of potato cultivars x nitrogen levels interaction on average tuber weight.

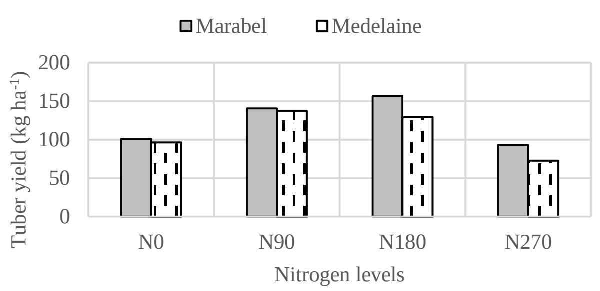

Fig. 3. Influence of potato cultivars x nitrogen levels interaction on tuber yield.

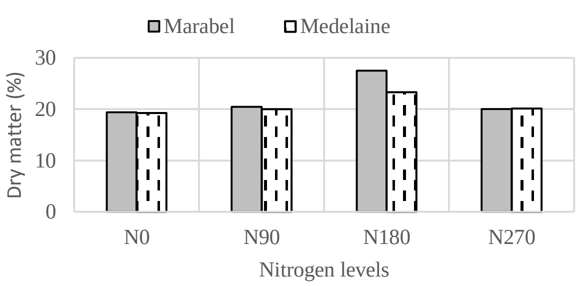

Fig. 4. Influence of potato cultivars x nitrogen levels interaction on dry matter.

The potato cultivars could not compensate for the yield loses owing to the low nitrogen dose. In two potato cultivars, maximum average tuber weight, tuber yield and dry matter were obtained from N_{180} treatment. Marabel cultivar responded better to N_{180} treatment than Medelaine cultivar. Recommendations of nitrogen dose are cultivar-soil specific and influenced growing conditions, though the level of 180 kg ha^{-1} N is optimum N rate for this ecology.

IV. Conclusion

It can be concluded that potato cultivar Marabel produced higher tuber yield than for potato cultivar Madeleine. The nitrogen levels had highly significant effect on all investigated characters. Nitrogen increases tuber yield and dry matter by influencing canopy temperature, leaf chlorophyll content, LAI, number of tubers and average tuber weight. It can be recommended that potato farmers in East Mediterranean climatic conditions may apply 180 kg ha^{-1} N to get high tuber yield.

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