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Research

EFFECT OF DEFICIT IRRIGATION AND POTASSIUM ON LEAF AREA, CHLOROPHYLL AND PHOTOSYNTHESIS IN POTATOES

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ABSTRACT

The research was conducted to determine the leaf area index, chlorophyll content (SPAD), and photosynthesis rate of potatoes grown under different irrigation levels and different potassium doses. The study was established in Niğde Ömer Halisdemir University, Ayhan Sahenk Faculty of Agricultural Sciences and Technologies, Department of Plant Production and Technologies Research and Application Area. Three different irrigation levels (I_{100}, I_{66}, and I_{33}) and six different potassium doses (0, 40, 80, 120, 160, and 200 kg/ha) were applied in this study. The experiment was established using a completely randomized design in split plots with four replications. Agria potato variety was used in this experiment. This variety is heavily preferred by the producers in the Niğde region. As a result of the study, leaf area index values changed ranged from 4.50 – 1.01, leaf chlorophyll content (SPAD) values 49.62 – 29.37, and photosynthesis rate values 23.92 – 3.55 µmol m^{-2} s^{-1}. As the amount of irrigation water decreased, it was negatively affected on the investigated properties. While I_{33} application was the irrigation application with the lowest results, the best results were obtained from the I_{100} application. Increasing doses of potassium had a positive effect but the best results were obtained from doses of 120 and 160 kg/ha. Because of these results, it is recommended to apply 120 to 160 kg/ha doses of potassium to the farmers.

Keywords: Irrigation, Potassium, Photosynthesis, Chlorophyll, Potato

1. INTRODUCTION

Globally potato production is approximately 380 million tons and ranked fourth after rice, wheat, and corn [1]. In Turkey, potato production is about 52 million tons and it is one of the most valuable dietary sources for human consumption due to its high nutritional value [2]. It can be consumed in different forms. Mainly, potato is preferred as table purpose potato, mashed potato, and potato flour. Recently, intensification of potato production was increased depending upon high-value food, easy digestion, having many uses, and adaptability to different environmental conditions [3].

Water is one of the most crucial resources for life and agriculture as well. Water resources have been gradually limited due to several reasons in the World and Turkey as well. One of the main reasons is the increase in population, which increases demand for water. Additionally, impact of climate change is also triggering water deficiency globally. Therefore, the reduction of available water causes problems for the growth and development of potatoes [4] due to drought [5]. Potato is sensitive to drought due to shallow root system and it causes devastating yield losses and deteriorates the quality of tubers [6, 7, 8]. Previous studies pointed that available water in soil should not be less than 50% for optimum yield because of sensitivity of potato to soil water deficit conditions [5, 9]. Additionally, potato plants will face drought stress conditions. One of the major responses of plants to drought stress is decreased growth and development of cell. Chlorophyll synthesis, photosynthesis, and respiration are negatively affected by drought and drought induces stomatal closure [10]. In addition, drought promotes leaf senescence, inhibits leaf growth and development, and decreases leaf area that directly decreases the photosynthetic rate of the plant [11]. All phenomenon influences drastically potato yields and quality. Therefore, the determination of efficient irrigation methods, irrigation schedule and water amount to be applied is the most important subject to cope with drought stress and its negative effects on potatoes. Therefore, different irrigation methods with high water use efficiency should be preferred such as drip irrigation [12].

Besides irrigation, other factors that are crucial for robust potato growth including fertilization. The length of the growing period is varied depending on the potato cultivar. The growing period of potatoes is changed between 100 to 150 days. Accordingly, it plays a role in the rate of nutrient uptake and type, time, and amount of fertilizer application [13]. For the production of 1 ton of tubers, the abundant amount of N, P_2O_5, K_2O, and CaO and less amount of MgO, S, Fe, Mn and Zn are used from the soil during the growing period of potato [14, 15, 16]. It is reported that K_2O is uptaken in huge amounts from soil and potato requires a large amount of K_2O compared to other elements. Potassium (K) is the primary and essential element for

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plant growth and physiology among the plant nutritions [3, 17]. Abiotic stress hinders plant productivity due to detrimental effects on plant growth, development, and physiological responses and it causes yield losses [18, 19]. Previous studies reported that potassium played important role in tolerance against abiotic stress and the biological function of plants [17]. In addition, potassium is responsible for biochemical and physiological processes during plant growth and development [20]. One of the functions of potassium is stomatal regulation to carry out the photosynthetic process. It also helps to transport water and nutrition [17]. Potassium assists to sustain water balance in the plant cell [21]. Therefore, potassium also contributes to the maintenance of the turgor pressure of the cell and the regulation of osmotic pressure under drought conditions [20, 22]. Earlier studies demonstrate that sufficient amount of potassium in plants or the supply of potassium to plants positively affected cell membrane stability [23], leaf area [24], chlorophyll contents, and photosynthetic rate [25].

It is obvious that potassium has a positive effect on regulation of biochemical and physiological processes in plants under drought conditions. The use of potassium with different irrigation methods can be beneficial to tolerate drought stress in plants. The current study aimed to determine the effect of potassium fertilization on morpho-physiological characteristics by using drip irrigation under drought conditions.

2. MATERIAL AND METHOD

This study was conducted in the field of research and application areas of the Department of Plant Production and Technologies in Niğde Ömer Halisdemir University in 2019. The field experiment consisted of a drip irrigation method with three different irrigation levels and six different potassium doses. The irrigation levels were full irrigation (I_{100}), 66% of full irrigation (I_{66}; 33% deficit), 33% of full irrigation (I_{33}; 66% deficit). The doses of potassium used as fertilizers were 0, 40, 80, 120, 160 ve 200 kg/ha. The experiment was laid out the randomized split plot experimental design with four replications. Three different irrigation levels in the main plot, different doses of potassium fertilizers were used in sub-plot in the experimental design. Each subplot had 4 rows with 0.30 m width and 5.10 m length. The rows were 0.70 m apart from each other. The six different doses of potassium sulphate consisting of 50% K_2O were applied to plots before planting. Planting was performed by using a semi-automatic potato planter machine in May 2019. The medium-early potato cultivar ‘Agria’ which is suitable for processing, was used in this study due to characteristic of yellow tuber and flesh colour, medium dry matter and starch content, high yielding, appropriate for french-fried, chips and baked potato, highly preferred producer product. Irrigation applications were carried out every five days. Drip irrigation lines were installed after planting. Soil moisture was determined at 0-30 cm and 30-60 cm soil depth before each irrigation. After 20 days of emergence, plants were irrigated until soil moisture was reached the field capacity. Later, three different irrigation levels (I_{33}, I_{66}, and I_{100}) were applied to all plots. Just after starting deficit irrigation treatment, the measurements of leaf area index, leaf chlorophyll content, and photosynthesis rate have been done at three different dates (28.07.2019, 16.08.2019, and 05.09.2019). The measurements were performed before irrigation. Chlorophyll content, leaf area index and photosynthesis rate were measured by using Minolta SPAD 502, LAI-2200 instrument, and LICOR-6400 portable photosynthesis device, respectively. The analysis of variance (ANOVA) according to the split plot design was used to determine the significance of the difference between the means. Then, the LSD test was used for the determination of different groups.

3. RESULTS AND DISCUSSION

The effect of different irrigation levels and potassium doses on leaf area index was given in Table 1. The results revealed that the limited irrigation and potassium doses had significant effects on leaf area at each of three different periods. The limited irrigation negatively affected the leaf area and as the severity of limited irrigation increased, the leaf area index decreased more. The lowest leaf area index was observed in I_{33} treatment for all three measurements. In addition, the mean value of leaf area index in I_{66} treatment was negatively affected compared to control (full irrigation). When first measurements were evaluated, increasing doses of potassium did not affect the leaf area index in I_{33} and I_{66} treatments. In I_{100} treatment, increasing doses of potassium, however, had a positive effect on leaf area index, and the highest value was observed at 200 kg/ha potassium. Second measurements showed that potassium doses were not significant for leaf area index in I_{33} treatment, unlike the first measurement. In I_{66} treatment, 80, 120, 160, and 200 kg/ha K doses resulted in a higher leaf area index than 0 and 40 kg/ha. In I_{100} treatment, increasing potassium doses had significant effect on leaf area index and increased the value of this trait however, the highest leaf area index was observed in 120, 160 and 200 kg/ha K. Considering the results of third measurement, there was a decrease in all applications as the extent of water scarcity and drought stress affected plants severely. The highest leaf area index was recorded at 200 kg/ha K for I_{33}, 200 kg/ha K for I_{66} and 200 kg/ha K for I_{100} applications. Drought stress negatively affects cell growth and development, therefore alters overall plant growth [26]. Upon continuous exposure to stress factors, plants close their stomata and photosynthesis is negatively affected. The plant growth and development retards and leaf area decreases as a consequence of a morphological outcome [27, 28, 29]. Potassium application to plants under drought stress help reducing the negative effects of stress and also has a positive effect on leaf area [24, 30]. In our study, although it was observed that limited irrigation decreased leaf area, increasing doses of potassium promoted increase in leaf area index.

Table 1. Mean values with LSD groups and ANOVA results of leaf area index under different irrigation levels, potassium doses and irrigation x potassium interaction

Applications		**Leaf area index**		
Irrigation levels (I) (%)	**Potassium doses (K) (kg/ha)**	**1 (28.07.2019)**	**2 (16.08.2019)**	**3 (05.09.2019)**
I_{33}	0	3.57 e	2.22 e	1.01 l
	40	3.57 e	2.32 e	1.07 l
	80	3.57 e	2.32 e	1.36 k
	120	3.70 e	2.32 e	1.60 j
	160	3.65 e	2.25 e	1.77 ıj
	200	3.67 e	2.20 e	1.90 ıh
	Avg.	**3.62**	**2.27**	**1.45**
I_{66}	0	3.72 de	2.37 e	1.82 ı
	40	3.70 de	2.42 e	2.07 gh
	80	3.82 de	2.75 d	2.20 gf
	120	3.77 de	2.85 d	2.35 f
	160	3.77 de	2.92 d	2.57 e
	200	3.82 de	2.80 d	2.65 de
	Avg.	**3.78**	**2.68**	**2.27**
I_{100}	0	3.80 de	3.47 c	2.67 cde
	40	4.00 dc	3.53 bc	2.80 dc
	80	4.20 bc	3.75 ba	2.87 c
	120	4.45 ba	3.80 a	3.27 b
	160	4.45 ba	3.92 a	3.45 ba
	200	4.50 a	3.88 a	3.50 a
	Avg.	**4.23**	**3.72**	**3.09**
LSD (%5)		0.27	0.25	0.20
ANOVA				
	Degre of Freedom	**Mean Square**	**Mean Square**	**Mean Square**
Replication	3	0.95	2.17	2.05
Irrigation	2	72.79**	404.30**	790.49**
Potassium	5	5.67**	6.52	68.38**
Irrigation x Potassium	10	2.45*	2.09*	0.78*
Error		0.03	0.03	0.02
Coefficient of variation		4.71	6.32	6.28

*P < 0.05, **P < 0.01

The effect of different irrigation regimes and potassium doses on chlorophyll content is given in Table 2. Deficit irrigation regimes and potassium doses had no significant effect on chlorophyll content according to data taken during first measurement day. Interaction between irrigation and potassium doses were found to be significant regarding chlorophyll content. Chlorophyll content was decreased based on reduction of irrigation levels. Potassium doses applied up to 120 kg/ha was increased chlorophyll content. However, the decrease was observed in chlorophyll content after treatment with 160 kg/ha and 200 kg/ha K doses. The highest chlorophyll content was determined during second measurement day under I_{33}-K_{120}, I_{66}-K_{120} and I_{100}-K_{120}. On the other hand, the highest chlorophyll content was recorded during third measurement day under I_{33}-K_{40}, I_{33}-K_{80}, I_{33}-K_{120}, I_{66}-K_{120} and I_{100}-K_{120}. Leaf chlorophyll content is one of the most important parameters affected by drought stress [11, 31]. It is known that chlorophyll content declines due to decreasing relative water content of plants under drought stress. However, it is known that potassium applied in increasing doses affects the chlorophyll content positively and tolerates stress in case of drought [25, 32]. In this study, chlorophyll content decreased as irrigation restriction increased, but it was determined that potassium applied up to 120 kg/ha K dose increased chlorophyll content in all irrigation applications compared to other potassium doses.

Table 2. Mean values with LSD groups and ANOVA results of leaf chlorophyll content (SPAD) under different irrigation levels, potassium doses and irrigation x potassium interaction

Applications		**Leaf chlorophyll content (SPAD)**		
Irrigation levels (I) (%)	**Potassium doses (K) (kg/ha)**	**1 (28.07.2019)**	**2 (16.08.2019)**	**3 (05.09.2019)**
I_{33}	0	48.00	42.15 k	30.72 gf
	40	48.47	42.23 jk	31.65 f
	80	48.87	43.90 ıj	31.95 f
	120	49.22	44.77 ıh	32.02 f
	160	48.07	43.32 ıjk	30.27 gf
	200	47.95	43.22 ıjk	29.37 g
	Avg.	**48.43**	**43.26**	**30.99**
I_{66}	0	48.37	46.40 hg	34.70 e
	40	48.42	46.72 fg	35.50 e
	80	48.70	46.72 fg	35.52 e
	120	49.07	48.30 efd	38.87 d
	160	48.22	47.32 efg	34.79 e
	200	48.15	47.27 efg	34.70 e
	Avg.	**48.48**	**47.12**	**35.68**
I_{100}	0	48.30	49.35 bcd	42.27 bc
	40	48.25	50.00 bc	44.17 ba
	80	48.45	51.00 ab	44.25 ba
	120	49.62	52.25 a	45.05 a
	160	48.48	48.70 ecd	41.42 c
	200	48.52	48.43 ecd	41.85 c
	Avg.	**48.60**	**49.95**	**43.16**
LSD (%5)		1.74	1.67	2.00
		ANOVA		
	Degre of Freedom	**Mean Square**	**Mean Square**	**Mean Square**
Replication	3	2.15	1.03	2.33
Irrigation	2	0.12	201.93**	496.13**
Potassium	5	1.48	7.43**	10.85**
Irrigation x Potassium	10	0.14	1.63*	1.13*
Error		1.48	1.33	1.82
Coefficient of variation		2.51	2.47	3.68

*P < 0.05, **P < 0.01

The effect of different irrigation regimes and potassium doses on photosynthesis rate is presented in Table 3. The differences were observed between different irrigation regimes and potassium doses according to results. The decrease of irrigation levels induced photosynthesis rate. The rate of photosynthesis measured in I_{33} was founded to be lower as compare to other irrigation regimes. On the other hand, the highest rate of photosynthesis was recorded in I_{100}.Drying and harvesting stage started depending upon the of deficit irrigation applied during field experiment. It is observed that potassium doses applied under different irrigation regimes were found to be statistically significant except first application date of I_{33}. The increase of potassium doses was positively affected photosynthesis rate. Additionally, the highest values occurred in 120 kg/ha K with I_{33}. According to results of first measurement date, the highest values were obtained with application of all doses of potassium under I_{66} as compare to control group. Treatment with 120 kg/ha K increase photosynthesis rate for other measurement date as well. The highest photosynthesis rate was noted with different doses of potassium in the second measurement date under I_{100} as compare to control group. Besides, 120 kg/ha and 160 kg/ha K showed better results for other measurements days as well. Plants subjected to drought stress due to deficit irrigation regimes. Therefore, the decline of water in plants are negatively affected photosynthesis [33]. One of the efficient way is that plant could avoid drought by closing stomata. Additionally, photosynthesis rate is negatively affected due to lack of sufficient amount of CO_2 [10, 34, 35]. Potassium have essential role on not only photosynthesis but also CO_2 fixation and transportation of photosynthesis product [22]. The increase of potassium in plants cause to increase of osmotic potential in plant cell. As a result, water enters to cell through opening of stomata and photosynthesis rate is positively affected [25]. Finally, current study suggested that potassium doses had positive effect on photosynthesis rate under deficit irrigation regimes.

Table 3. Mean values with LSD groups and ANOVA results of photosynthesis rate of potato under different irrigation levels, potassium doses and irrigation x potassium interaction

Applications		**Photosynthesis rate (µmol m^{-2} s^{-1})**		
Irrigation levels (I) (%)	**Potassium doses (K) (kg/ha)**	**1 (28.07.2019)**	**2 (16.08.2019)**	**3 (05.09.2019)**
I_{33}	0	21.62 d	13.30 g	3.92 hg
	40	21.60 d	14.00 gf	4.05 hg
	80	21.92 d	14.02 gf	4.22 hg
	120	21.85 d	14.60 f	4.52 g
	160	21.57 d	13.37 g	3.95 hg
	200	21.62 d	13.50 g	3.55 h
	Avg.	**21.69**	**13.79**	**4.03**
I_{66}	0	21.90 d	15.87 f	5.65 f
	40	22.15 dc	16.30 de	5.71 f
	80	22.17 dc	16.52 de	6.15 fe
	120	22.42 dc	17.65 c	7.17 dc
	160	22.27 dc	17.02 dc	5.67 f
	200	22.42 dc	16.82 dc	5.90 fe
	Avg.	**22.22**	**16.69**	**5.04**
I_{100}	0	22.35 dc	20.80 b	6.62 de
	40	23.15 bac	22.17 a	7.57 c
	80	23.25 bac	22.72 a	9.00 b
	120	23.90 a	22.85 a	10.15 a
	160	23.95 a	22.40 a	8.69 b
	200	23.60 ba	22.15 a	8.87 b
	Avg.	**23.36**	**22.18**	**8.48**
LSD (%5)		1.14	0.87	0.87
		ANOVA		
	Degre of Freedom	**Mean Square**	**Mean Square**	**Mean Square**
Replication	3	0.55	1.08	1.05
Irrigation	2	26.16**	1349.16**	310.59**
Potassium	5	1.55**	11.27**	12.98**
Irrigation x Potassium	10	0.58**	1.62**	3.69**
Error		0.65	0.32	0.38
Coefficient of variation		3.61	3.23	10.00

*P < 0.05, **P < 0.01

4. CONCLUSION

The reduction of water supplies induces to less irrigation of plants that needed for their life cycle. It is obvious that plants suffer from drought stress during their growth and development. It is known that potassium provides to maintain water balance and to tolerate against drought stress. The three different irrigation regimes and six different potassium doses were used for current study. The important parameters like leaf area index, chlorophyll content and photosynthesis rate was observed. Those parameters were negatively affected by limiting plant growth and development under deficit irrigation regimes. The increase of potassium dosses had significant both full irrigation and deficit irrigation regimes on those parameters except first measurement day for I_{33}. As a consequence, positive effect of 120 kg/ha and160 kg/ha K applied under full irrigation (I_{100}) and deficit irrigation conditions (I_{66} and I_{33}) were determined and recommended to producer.

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