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EVALUATION OF YIELD AND SOME OF PHYSIOLOGICAL INDICES OF POTATO CULTIVARS IN RELATION TO CHEMICAL, BIOLOGIC AND MANURE FERTILIZERS

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ABSTRACT. In order to evaluate yield and some of physiological indices of potato cultivars in relation to different kinds of manures, strip plot layout within a randomized complete block design with three replications was used. Three levels of fertilizer were included manure (t/ha) (20, 40 and 60 t/ha), biologic fertilizer (ml/ha) (0, 100 and 200 ml/ha), and chemical fertilizer (kg/ha) (175, 350, and 525 kg/ha). Cultivars were Marfona, Maradona and Ramus. Marfona had obtained the maximum plant height, total dry matter, LAI, tuber yield, dry matter of tuber, the number of tuber and tuber weight. Application of 60 t/ha manure fertilizer together with Marfona produced the highest yield. In this experiment, fertilizer showed significant effects on potato cultivars yield and physiological indices. Marfona and Ramus had obtained the highest and the lowest total dry matter, respectively. The maximum LAI was related to application of 60 t/ha manure fertilizer, and the minimum one was obtained for application of 40 t/ha manure fertilizer. In cultivar treatments, the highest LAI was obtained for Marfona, followed by Maradona and Ramus. The maximum and the minimum crop growth rate (CGR) was related to chemical and biological fertilizer, respectively. The maximum CGR was related to Marfona, than those of other cultivars. There were not any significant differences among different fertilizers in net assimilation ratio (NAR), fertilizer levels and various cultivars. Thus, it can ve suggested that in order to increasing yield, total dry matter, crop growth rate and other physiological indices should be applied 60 t/ha manure fertilizer with Marfona cultivar in Fereydan region of Esfahan, Iran.

Keywords: LAI; CGR; NAR; total dry matter; tuber weight.

INTRODUCTION

The need for more food and limitations in both new land and conventional technology all point to

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the need for crop improvement as a major means to significantly increase world food production (Soleymani *et al.,* 2016; Soleymani & Shahrajabian, 2017; Shahrajabian *et al.,* 2017; Yong *et al.,* 2017). As a result, understanding physiological basis of crop is critical for the rationale design of agricultural practices, as well as breeding strategies (Shahrajabian *et al.,* 2011; Soleymani *et al.,* 2012; Alikhani *et al.,* 2012). Potato (*Solanum tuberosum* L.) has the fourth rank among foods in terms of importance after wheat, rice and corn in the world, and in Iran it is considered as an important strategic product, having the second rank in terms of production and this one according to its importance among other produced foods (Germchi *et al.,* 2011; Ati *et al.,* 2012; Abdollahi & Soleymani, 2014). The share of solar energy for an increase of dry matter and tubers produced from a potato plant, is determined between a production of photosynthetic apparatus, especially by leaves, and loss caused by this apparatus, as well as by non-photosynthetic organs (Jůzl & Štefl, 2002). Nátr (1972) mentions that the produced dry matter is created by photosynthesis of the whole assimilatory system. Commercially, available chemical fertilizers are used extensively in potato cropping systems, which have been shown to improve yield and quality of potato tubers (He *et al.,* 2011). Bourke (1984) and Soleymani *et al.* (2013) reported the significant cultivar differences for total dry weight (TDW), leaf area index (LAI) and crop growth rate (CGR).

Bourke (1985) suggested that nitrogen (N) influenced yield by increasing leaf area duration, which in turn increased weight and hence tuber yield. Morphophysiological indexes, such as leaf area and plant height, complement plant growth quantitative analysis and enable the determination of the effects of the use of different crop management techniques in potato (Pohl *et al.,* 2011; Soleymani *et al.,* 2011). Large differences in total dry weight per plant occurred between cultivars (Bourke, 1984). Higher tuber yield in potato cultivars is dependent both on high total plant dry matter production and, to a lesser degree, a large proportion of the dry matter being diverted into the tubers. Gordon *et al.* (1997) showed that Atlantic and Norchip varieties has a maximum LAI, between 3 and 4, while Monona had a maximum of around 2 m^2 leaf/m^2 ground. Murphy *et al.* (1996) concluded that leaf area is influenced by genotype. Furthermore, Muchow (1988) reported that appropriate fertilization affects dry matter production by influencing leaf area development, leaf area maintenance and photosynthetic efficiency of the leaf area. Growth indices are useful for interpreting plant reaction to environmental factors (Valadabadi & Farahani, 2010). Gordon *et al.* (1997) showed that historically models of potato LAI have varied both in their complexity and physiological implications. Growth analysis is a way to assess what events occurs during plant growth (Hokmalipour & Darbandi, 2011; Shahrajabian & Soleymani, 2017). Growth analysis is a suitable method for plant response to different environmental conditions during life (Tesar, 1984; Shahrajabian *et al.,* 2013). Murphy *et al.* (1996) and Sharifi *et al.* (2011) stated that the physiological indices, such as LAI, TDM and CGR, are influenced by genotypes, plant population, climate and soil fertility. Sharifi *et al.* (2011) noted that dry matter production of crops needs on the amount of intercepting solar radiation and its conversion to chemical energy. Rao *et al.* (2002) suggested that LAI and leaves architecture are two main characteristics that define light interception in the canopy.

The aim of this study was to evaluate the yield and some of physiological indices of potato cultivars in relation to different fertilizers in Fereydan, Esfahan, Iran.

MATERIALS AND METHODS

Strip plot layout within a randomized complete block design with three replications was used to evaluate potato yield and chemical concentration of some elements at Fereydan Research Station (33°10/N, 50°29/E, altitude 2300 m above sea level), Esfahan, Iran, in 2012. Three levels of fertilizer were included manure (t/ha) (20, 40 and 60 t/ha), biologic fertilizer (ml/ha) (0, 100 and 200 ml/ha), and chemical fertilizer (kg/ha) (175, 350, and 525 kg/ha). Cultivars were Marfona, Maradona and Ramus. On the basis of soil analysis, the organic carbon was 0.07%, moreover, cadmium and lead concentration was 0.08 and 14/8 mg/kg.

Each plot had six rows, the length and width of each row was 4 and 3 m, respectively. Fertilizer was used as main plot and cultivar was used as sub plots. The soil preparation consisted of moldboards ploughing, followed by discing and smoothing with a land leveler. On the basis of soil analysis of the field, one third of nitrogen and micronutrients and all manure fertilizers were used before plantation, and then disked again. One third of nitrogen was used in putting soil on the crops and one third was applied in flowering stage. Biologic fertilizer was used in two stages, half of it was applied in putting soil on the crops and another half was applied in flowering stage with foliar application method. All tubers were planted by skillful workers. The distance between tubers in each row was 25 cm. Each plot had four lines with 6 m lengths. The first irrigation was done three days before plantation, the second irrigation was done after plantation, and other irrigation intervals were 14 days. The total number of irrigations was 14 times. All practices, such as irrigation and control of weeds, pests and diseases were done regularly during period. Control of the pests and fungus disease was done respectively by use of 250 mL ha^{-1} Confidor and 400 g ha^{1} Equation-pro. Leaf area index was determined by dividing leaf area over ground area and was estimated using of equation 2. The variances trend of total dry matter (TDM), leaf area index (LAI), net assimilation ration (NAR), and crop growth rate (CGR) were determined with using of 1-4 equations (Acquaah, 2002; Gupta & Gupta, 2005).

$$W = e^{a2+b2t+c2t2} \quad (1)$$

$$LAI = e^{a1+b1t+c1t2} \quad (2)$$

$$NAR = (b2 + 2c2t)e^{(a2-a1)+(b2-b1)t+(c2-c1)t2} \quad (3)$$

$$CGR = NAR \times LAI = (b2 + 2c2t)e^{a2+b2t+c2t2} \quad (4)$$

Data were subjected to analysis a variance (ANOVA) using statistical analysis system, followed by Duncan's multiple range test and differences were considered significant at $P<0.05$ by MSTAT-C software (version 2.10).

RESULTS AND DISCUSSION

The highest plant height, which had significant differences with other treatments, was obtained for chemical fertilizer. Moreover, usage of chemical fertilizer had obtained the maximum number of stem per m^2 and LAI, which had just significant difference with biologic fertilizer. The maximum and the minimum total dry matter was obtained for chemical and biologic fertilizer, respectively. Although the highest tuber yield and dry matter was shown in usage chemical fertilizer, in both experimental characteristics, it had just significant differences with biologic fertilizer. The higher value of number of tuber per m^2 was related to manure, followed by chemical and biologic fertilizer. Chemical fertilizer had obtained the maximum tuber weight with less than 35 mm diameter, between 35-70 mm diameter, and more than 70 mm diameter was obtained for chemical fertilizer, which just had significant differences with manure fertilizer. The highest plant height (64.56 cm) and total dry matter (1347 g/m^2) was related to Marfona, which had no significant differences with other treatments. Maradona and Marfona had obtained the maximum number of stem per m^2 and LAI. Moreover, there were not any significant differences between these two cultivars in two experimental characteristics. Marfona also had obtained the maximum tuber yield (28.27 t/ha), dry matter of tuber (610.1 g/m^2), and the number of tuber per m^2 (49.74), which just had significant differences with Ramus. The higher value of tuber weight with less than 35 mm diameter, 35-70 mm diameter and more than 70 mm diameter was related to Marfona, than those of other cultivars (*Table 1*).

The highest plant height, number of stem per m^2, total dry matter, LAI, tuber yield and dry matter of tuber were related to application of 60 t/ha manure. Although, the highest number of tuber per m^2 was related to application 40 t/ha manure, which had significant difference with 20 t/ha, however, its difference with 60 t/ha was not meaningful. The higher value of tuber weight with less than 35 mm diameter, 35-70 mm diameter and tuber weight with more than 70 mm diameter was obtained for usage of 60 t/ha. The maximum plant height, number of stem per m^2, total dry matter, LAI, and tuber yield was related to application of 200 ml/ha biologic fertilizer.

Table 1 - Mean comparison for experimental characteristics

Treatment	Plant height (cm)	The number of stem per m^2	Total dry matter (g/m^2)	LAI	Tuber yield (t/ha)	Dry matter of tuber (g/m^2)	The number of tuber per m^2	Tuber weight with less than 35 mm diameter (kg/ha)	Tuber weight with 35-70 mm diameter (kg/ha)	Tuber weight with more than 70 mm diameter (kg/ha)
Fertilizer										
Manure	58.70b	39.78a	1295b	3.75a	28.96a	632.6a	51.74a	2755.7a	14910.4a	11220.1a
Biologic	57.15b	33.48b	1116c	3.43b	19.57b	432.3b	42.89b	1864.8b	10700.0b	7024.0b
Chemical	66.11a	39.81a	1375a	3.94a	30.70a	661.1a	51.30a	2918.9a	15080.5a	12820.2a
Cultivar										
Marfona	64.56a	39.37a	1347a	3.83a	28.27a	610.1a	49.74a	2685.6a	1444.4a	11150.1a
Maradona	59.56b	39.67a	1271b	3.79a	27.08a	582.9a	48.93ab	2568.5a	13840.3a	10670.0a
Ramus	57.85c	34.04b	1168c	3.50b	23.87b	524.0b	47.26b	2284.2b	12410.2b	9251.2b

Common letters within each column do not differ significantly.

Table 2 - Mean comparison for different level and kind of fertilizers

Treatment	Plant height (cm)	The number of stem per m^2	Total dry matter (g/m^2)	LAI	Tuber yield (t/ha)	Dry matter of tuber (g/m^2)	The number of tuber per m^2	Tuber weight with less than 35 mm diameter (kg/ha)	Tuber weight with 35-70 mm diameter (kg/ha)	Tuber weight with more than 70 mm diameter (kg/ha)
Manure (t/ha)										
20	57.89cd	39.78bc	1208de	3.59cd	26.16bc	573.33b	49.89b	2441.11bc	13411.11bc	10081.11bc
40	58.33cd	39.33abc	1277cd	3.72bc	29.9b	652.11ab	53a	2854.44ab	15388.89ab	11656.67b
60	59.89c	41.22ab	1399ab	3.94b	30.82ab	672.22ab	52.33a	2970ab	15922.22ab	11930b
Biologic (ml/ha)										
0	55.11e	30.89d	944f	3.36d	18.1d	396.11c	42.67c	1725.56d	10200d	6163.33d
100	56.44de	32.56d	1127e	3.42d	19.48d	424c	42.78c	1852.22d	10870d	6811.11d
200	59.89c	37c	1225de	3.53cd	21.14cd	449.67c	43.22c	2013.33cd	11033.4cd	8097.78cd
Chemical (kg/ha)										
175	64.89b	38.22c	1249d	3.71bc	27.51b	602.11b	49.78b	2615.56b	13755.56b	11495.56b
350	65.44b	39.44abc	1377bc	3.92b	29.1b	617.22b	52a	2751.11b	14222.22b	12104.4b
525	68a	41.78a	1497a	4.2a	35.54a	764.11a	52.11a	3387.78a	17266.67a	14873.33a

Common letters within each column do not differ significantly.

There were not any significant differences among treatments in dry matter of tuber and number of tuber per m^2. The higher value of tuber weight with less than 35 mm diameter, 35-70 mm diameter, and tuber weight with more than 70 mm diameter was obtained for usage of 200 ml/ha, compare with those of other treatments. The higher values plant height, the number of stem per m^2, total dry matter, LAI, tuber yield and fry matter of tuber were obtained for application 525 kg/ha chemical fertilizer, compare with those values of other treatments. In spite the fact that the highest number of tuber per m^2 was obtained for usage of 525 kg/ha chemical fertilizer, there was no significant difference between 350 kg/ha and 525 kg/ha. However, both these treatments had significant differences with application of 175 kg/ha. The maximum tuber weight with less than 35 mm diameter, 35-70 mm diameter, and tuber weight with more than 70 mm diameter were obtained for 525 kg/ha, compare with those of other treatments (*Table 2*).

Total dry matter (TDM)

The influence of different kinds of fertilizer, fertilizer levels and cultivar on total dry matter trend was measured from 35 days after planting until the final maturity. From 15 days after the first sampling until 80 days after planting, the total dry matter trend increased slowly, then it increased rapidly (*Figs. 1 and 2*). The highest total dry matter was obtained for 80 days after planting. Then, from 80 days after planting until harvest time, accumulated dry matter decreased due to increasing aging of leaves, decreasing of leaf area index (*Fig. 3*). The increase in dry matter is related to accelerating the photosynthesis activity, that is caused dry matter accumulation increased (Sharifi & Raey, 2011; Soleymani & Shahrajabian, 2012). The highest total dry matter was obtained for chemical fertilizer, manure fertilizer and biological fertilizer, respectively. Increasing leaf area index is one of the ways of increasing the capture of solar radiation within canopy and production of dry matter (Sharifi & Raey, 2011).

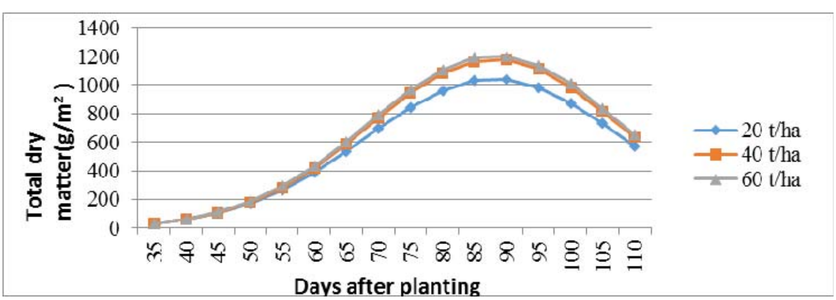

Figure 1 - The effect of manure fertilizer on TDM

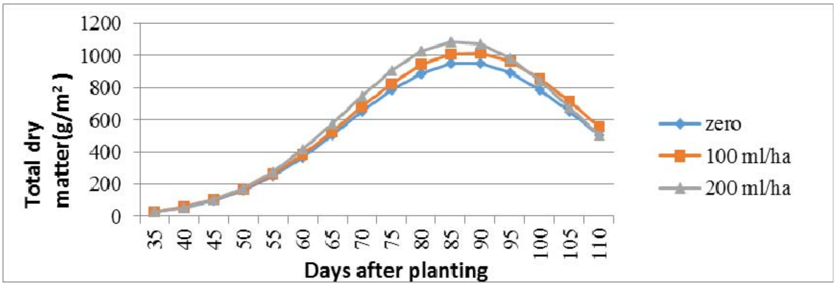

Figure 2 - The effect of bio-fertilizer on TDM

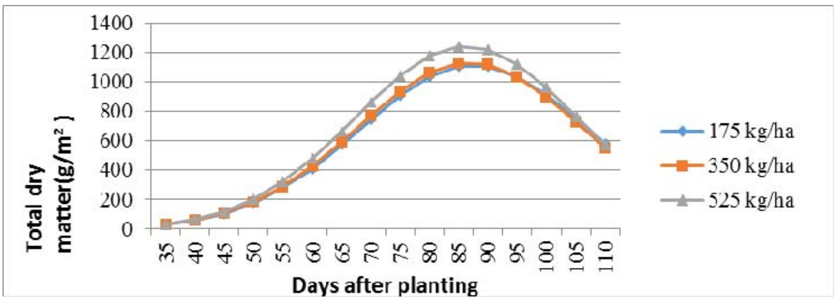

Figure 3 - The effect of chemical fertilizer on TDM

The maximum total dry matter was related to application of 60 t/ha manure fertilizer, 200 ml/ha biological fertilizer and 525 kg/ha chemical fertilizer. Marfona and Ramus had obtained the highest and the lowest total dry matter, respectively. The efficiency of the conversion of intercepted solar radiation in to dry matter decrease with decreasing of leaf area index (Sharifi & Raey, 2011). Total dry matter trend (TDM) and crop growth rate (CGR) are the most important traits in plant growth analysis (Hokmalipour & Darbandi, 2011).

Leaf area index (LAI)

LAI trend in all growth and development stages for different treatments were measured. Leaf area index increased during plant growth and reached to a maximum level at 65 days after planting, which was changed from 3.3 to 4.2. From 65 days after sowing until harvest time, leaf area index decreased due to increasing aging of leaves, shading and competition between plants for light and other resources (*Figs. 4 and 5*). For fertilizer treatments, the maximum LAI was obtained for chemical fertilizer, followed by manure and biological fertilizer (*Fig. 6*). For different levels of fertilizer, the highest LAI was related to application of 60 t/ha manure fertilizer, and the lowest one was obtained for application of 40 t/ha manure fertilizer. In biological fertilizer, the maximum LAI was achieved in usage of 200 ml per ha; moreover, there was no difference between control treatment and 100 ml per ha. Chemical fertilizer of 525 kg/ha had obtained the highest LAI, followed by 350 kg/ha. In contrast, the minimum LAI was achieved in application of 175 kg/ha. In cultivar treatments, the highest LAI was obtained for Marfona, followed by Maradona and Ramus. Leaf area index is an index of the size of the photosynthetic system (Soleymani & Shahrajabian, 2013).

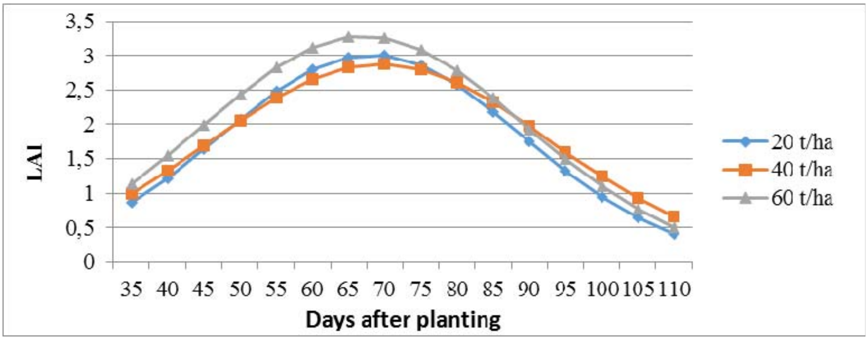

Figure 4 - The effect of manure fertilizer on LAI

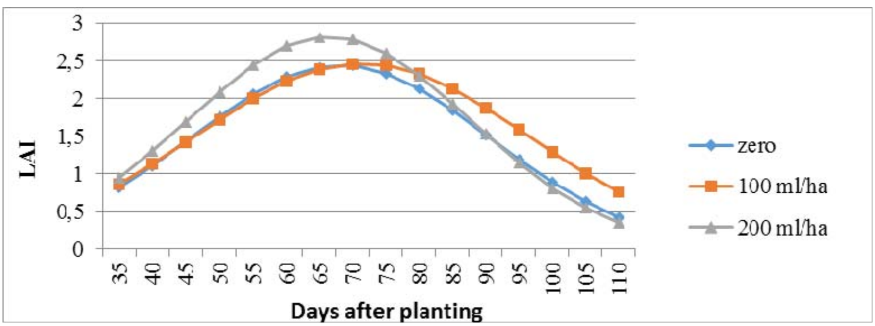

Figure 5 - The effect of bio-fertilizer on LAI

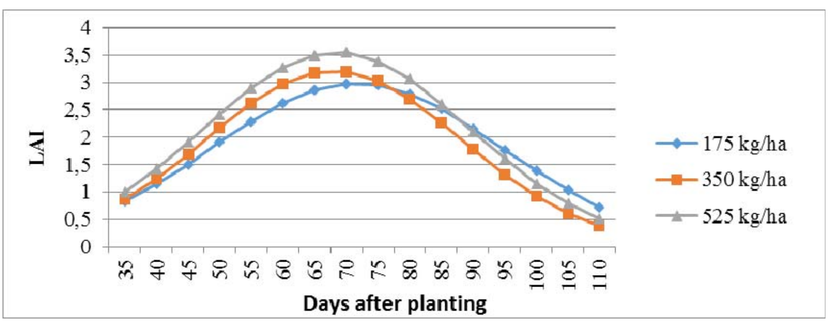

Figure 6 - The effect of chemical fertilizer on LAI

Crop growth rate (CGR)

Study of trend of variances crop growth rate showed that, in all treatments, the crop growth rate was low in the beginning of sampling, thereafter increased considerably up to 40 days after planting (10 $g/m^2/day$), with a peak in 65 days after planting (35 $g/m^2/day$), then showed a declining trend after that (*Figs. 7 and 8*). Should be noted that negative values of crop growth rate is due to loss of leaves at the end of the growing season (Hokmalipour & Darbandi, 2011). In 80 days after planting, crop growth rate was zero, then it had negative trend until 105 days after planting, which became stable (*Fig. 9*). The increase in CGR may be due to accelerating the photosynthesis activity. The decrease in crop growth rate towards maturity is due to senescence of leaves and decrease of leaf area index (Sharifi & Raey, 2011). The maximum and the minimum CGR was related to chemical and biological fertilizer, respectively (Beadle, 1987). Crop growth rate in the early stages due to the complete absence of vegetation and low percentage of light absorption is lower, but with the rapid increase in the rate of plant growth, that occurs because the level of developed leaves and thus absorption of solar radiation increases.

For manure fertilizer, the maximum CGR was obtained for 40 t/ha, followed by 60 t/ha. However, the lowest CGR was related to 20 t/ha. For biological fertilizer, the highest value of CGR was related to application of 200 ml/ha than those of other treatments. In chemical fertilizer, the maximum value was related to application of 525 kg/ha, and after that the highest value was achieved in 350 kg/ha. However, the lowest CGR was obtained for usage of 175 kg/ha. For cultivar treatments, the maximum CGR was related to Marfona, than those of other cultivars. CGR is an index of crop growth, which can be used to indicate the change in crop growth over time on an individual plant basis, for a population of plants or for a community. CGR is directly affected by light interception by the crop.

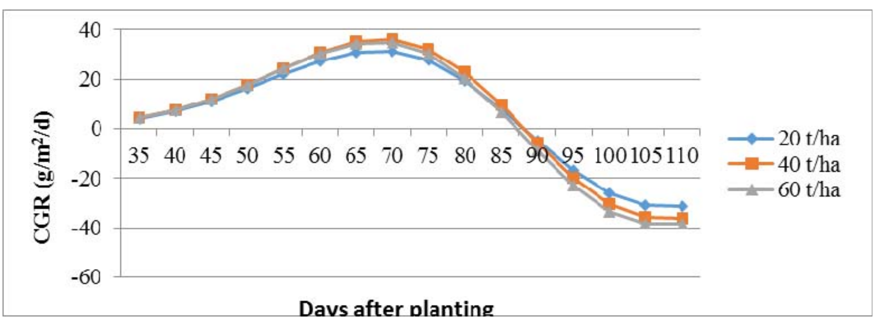

Figure 7 - The effect of manure fertilizer on CGR

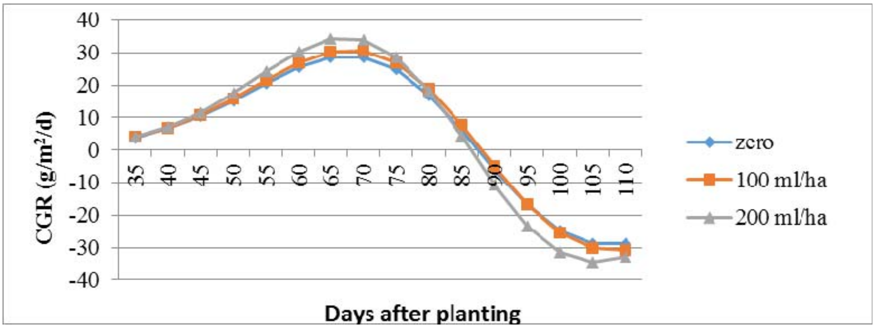

Figure 8 - The effect of bio-fertilizer on CGR

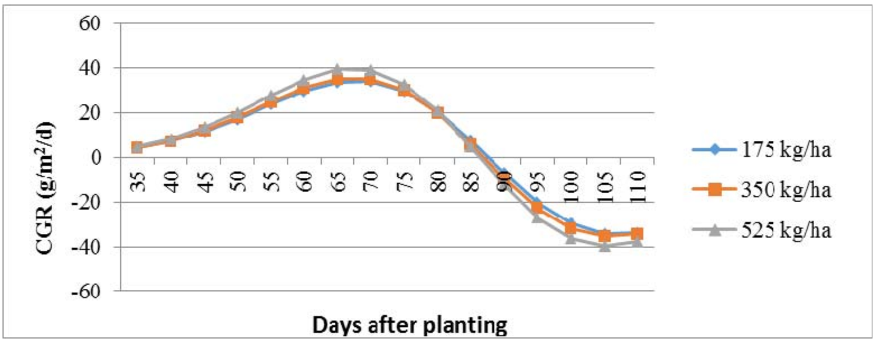

Figure 9 - The effect of chemical fertilizer on CGR

Net assimilation ratio (NAR)

Study of trend of net assimilation ration showed that, in all treatments, the NAR was low in the beginning of sampling, thereafter increased considerably up to 65 days after planting, which was 10 g/m^2/day. Then showed a declining trend after that toward zero (85 days after planting), then it had negative trend (*Figs. 10 and 11*). There were not any significant differences among different fertilizers, fertilizer levels and various cultivars. Net assimilation rate (NAR) is an indirect photosynthetic activity (*Fig. 12*). This is based on the principle that the increase in dry weight of plants in a given period is a measure of net photosynthesis. Growth analysis is still the most simple and precise method to evaluate the contribution of different physiological processes in plant development (Soleymani *et al.*, 2010; Soleymani & Shahrajabian, 2013; Sharifi & Raey, 2011). Hokmalipour & Darbandi (2011) indicated that physiological growth analysis is the important in prediction of yield.

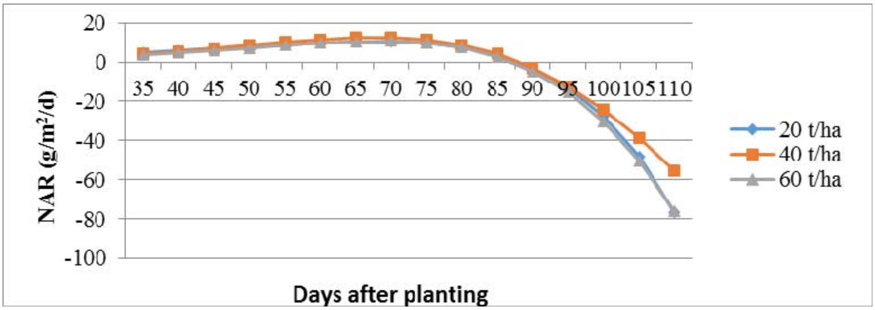

Figure 10 - The effect of manure fertilizer on NAR

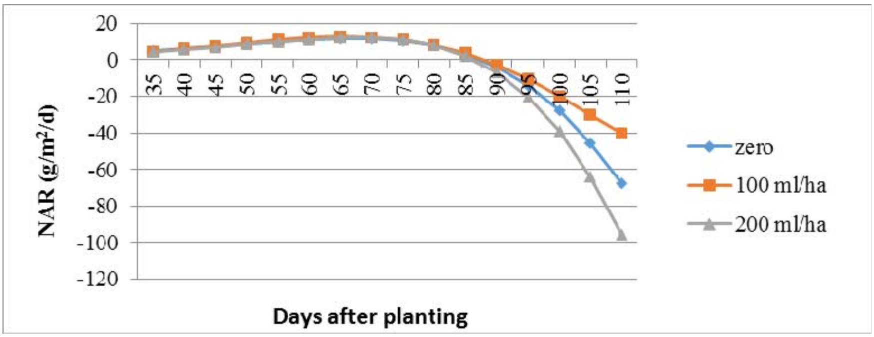

Figure 11 - The effect of bio-fertilizer on NAR

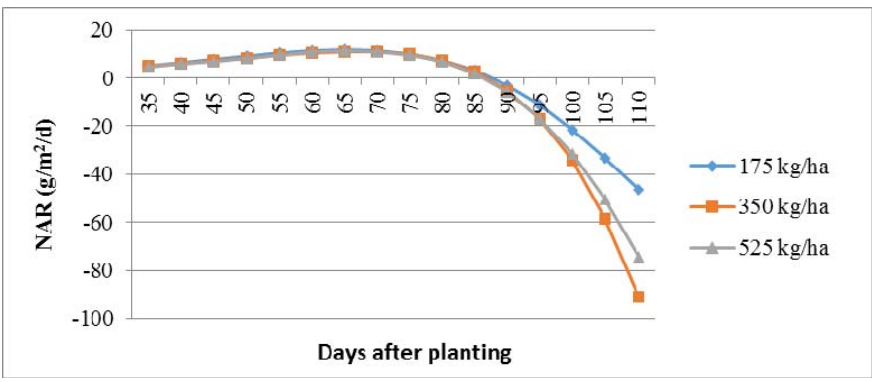

Figure 12- The effect of chemical fertilizer on NAR

CONCLUSION

Application of 60 t/ha manure, 200 ml/ha biologic fertilizer, and 525 kg/ha chemical fertilizer had obtained the highest plant height, the number of stem, total dry matter, LAI, tuber yield, dry matter of tuber and tuber weight. Marfona had obtained the maximum plant height, total dry matter, LAI, tuber yield, dry matter of tuber, the number of tuber and tuber weight. Application of 60 t/ha manure, 200 ml/ha biologic fertilizer, 525 kg/ha chemical fertilizer was obtained the highest potato tuber yield and weight. Application of 60 t/ha manure fertilizer together with Marfona produced the highest yield. The positive effects of manure application on the growth and yield of potato are a common phenomenon, as manures provide nutrients to the plants. It can be concluded that manures was effective in improving potato growth.

In this experiment, fertilizer showed significant effects on potato cultivars yield and physiological indices. The maximum total dry matter was related to application of 60 t/ha manure fertilizer, 200 ml/ha biological fertilizer and 525 kg/ha chemical fertilizer. Marfona and Ramus had obtained the highest and the lowest total dry matter, respectively. The highest LAI was related to application of 60 t/ha manure fertilizer, and the lowest one was obtained for application of 40 t/ha manure fertilizer. In cultivar treatments, the highest LAI was obtained for Marfona, followed by Maradona and Ramus. The maximum and the minimum CGR was related to chemical and biological fertilizer, respectively. The maximum CGR was related to Marfona, than those of other cultivars. There were not any significant differences among different fertilizers in NAR, fertilizer levels and various cultivars. Consequently, our finding may give applicable advice to farmers and agricultural researchers for management and proper use of fertilizer in farming of potato cultivars.

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