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Evaluation the Quantitative Characteristics of Potato Cultivars Affected Foliar Application of Indole-3-Acetic Acid and Weed Management

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ABSTRACT

BACKGROUND: Using plant hormones is an effective way to increase potato yield. Some plant hormones, such as gibberellic acid, cytokinin, and auxin, can stimulate the growth of potato roots and leaves, and among their other effects are regulating plant growth and development.

OBJECTIVES: This experiment was conducted in order to assess the effect of growth regulator (IAA hormone foliar application) and weed control on growth indices, crop production and morphological traits of the potato cultivars during two crop years in Bardsir region.

METHODS: This research was done at the Bardsir agricultural college, Kerman province(Iran) in 2017-2018 cropping seasons. The study was consisted of a split factorial using Randomized Complete Block Design (RCBD) with three replications. The two potato cultivars (Milva and Sante), as the first factor placed in the main plots, and three levels of foliar spraying of indole acetic acid (IAA) hormone (including of non-use, 200 and 400 ppm), and weed control (including of the pre-emergence application of metribuzin herbicide with an amount of 750 $g.ha^{-1}$, the two-stage application of metribuzin in the form of split [the pre-emergence application (500 $g.ha^{-1}$) + the post emergence application (250 $g.ha^{-1}$)], manual weeding and without weed control were factorially as the secondary factor were also placed in sub-plots.

RESULT: The results showed that increasing auxin from no consumption to 400 ppm significantly increased dry and fresh weight of potato tuber, tuber diameter, tuber yield, dry biomass and leaf area index. The application of auxin at 400 ppm significantly increased the weed biomass at the time of potato harvest. The highest leaf area index of 3.46 was observed in Milva cultivar when 400 ppm of indole-3-acetic acid was used. Weed control during the two-step application of metribuzin was recorded with an increase ratio of 15 to 39% compared to the control without treatment.

CONCLUSION: The highest yield of potato tuber was obtained under two-step application conditions of metribuzin and 400 ppm auxin at the rate of 38055.33$kg.ha^{-1}$.

KEYWORDS: *Growth indices, IAA, Leaf area, Tuber yield, Weed control.*

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1. BACKGROUND

Potato ranks fifth after cereals such as wheat, rice, corn and barley in terms of nutritional importance. In terms of production quantity, potato is the fourth crop in the world after wheat, rice and corn (El-Sayed, *et al*., 2015) and its global production reached 412 million tons in 2017, which is approximately equivalent to 55 kg per person. In recent years, the use of plant growth regulators in addition to herbicides, fungicides and insecticides has been expanded in modern agriculture. The use of these substances can significantly have a positive effect on the yield and qualitative characteristics of the crop plant, increasing the resistance of the plant against stress factors and the occurrence of disease (Wierzbowska *et al*., 2016). Hormonal regulation of tuber formation in potato has particular important. For this reason, the beginning of studies on the effect of plant hormones on the formation of potato tubers was considered immediately after plant hormones were chemically identified (Kolachevskaya *et al*., 2019). Auxin is effective in cell division, tissue growth, leaf area increase, formation of photosynthetic pigments, phototropism, gravitropism, terminal dominance, stimulation of lateral root growth, differentiation of vascular tissues, embryo development, aging, fruit formation and ripening (Naeem *et al*., 2004). An increase in auxin content along with a decrease in gibberellin content in the area near the end of the stolon leads to the stimulation of tuber formation in potato. (Roumeliotis *et al*., 2013). Therefore, auxin foliar spraying can affect the amount of tuber formation, the average weight of the tuber and, as a result, the yield of potatoes (Kolachevskaya *et al*., 2019). Among the types of auxins, there are auxin inform of dole-3-acetic acid (IAA), 4-chloroindoleacetic acid (4-Cl-IAA), phenylacetic acid (PAA), synthetic vaccines to naphthalene acetic acid (NAA), 2-4-dichlorophenoxyacetic acid (2,4-D). During foliar spraying of crops with plant hormones, weeds are also affected. Increasing the concentration of auxin hormone can have a significant effect on the number and dry weight of weeds and absorption of nutrients by weeds (El-Metwally *et al*., 2015). Weeds compete with the crop for water, nutrients, light and carbon dioxide, causing a decrease in the quantitative and qualitative yield of the crop (Hance *et al*., 1990). Therefore, considering the positive effect of plant hormones on weed growth, weed control is more important when using plant hormones, including auxin.

2. OBJECTIVES

This study was done to assess effect of growth regulator (IAA hormone foliar application) and weed control on growth indices, crop production and morphological traits of potato cultivars.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This research was conducted during 2015-2016 and 2016-2016 cropping seasons in the field of Bardsir Agricultural Academy located in Kerman province (Iran) with latitude 29° 55 north and longitude 56° 34 east and 2040 m above sea level. Before preparing the

land, samples were taken from the field soil at a depth of 30 cm to determine the physical and chemical properties of the soil. The results of field soil analysis are shown in table 1 and climatic characteristics including temperature and rainfall during two growing seasons are also shown in table 2. The study was consisted of a split factorial using Randomized Complete Block Design (RCBD) with three replications. The two potato cultivars [Sante (V_1) and Milva(V_2)], as the first factor in the main plots, and three levels of foliar spraying of indole acetic acid (auxin) hormone [including of non-use (A_0), 200 (A_1) and 400 (A_2) ppm], and weed control (including of the pre-emergence application of metribuzin herbicide with an amount of 750 g.ha^{-1} (H_1), the two-stage application of metribuzin in the form of split (H_2) [the pre-emergence application (500 g.ha^{-1}) + the post emergence application (250 g.ha^{-1}), manual weeding (H_3) and without weed control (H_4) (control)] were factorially as the secondary factor were also in the sub-plots.

Table 1. Chemical and physical characteristics of the experimental soil

Sampling depth (cm)	**pH**	**EC (ds.m^{-1})**
0-30	7.66	2.84
K (ppm)	**Sand (%)**	**Silt (%)**
180.0	38	42
OC (%)	**Clay (%)**	**N (%)**
0.56	24	0.05
Texture soil	**P (ppm)**	**ρ_b (gr.m^{-3})**
Clay loam	12.0	1.5

Table 2. Average monthly rainfall and temperature in Bardsir city

Year	Rainfall/Temperature	April	May	June	July	August
2016-17	**Rainfall (mm)**	9.5	12.0	0.0	0.0	0.0
	Temperature (°C)	12.2	18.9	22.2	25.0	22.9
2017-18	**Rainfall (mm)**	12.0	6.5	1.5	0.0	0.0
	Temperature (°C)	14.9	18.6	24.6	24.4	22.3

3.2. Farm management

Potato cultivars were planted with a row spacing of 25 cm in 5 meter rows with a distance of 75 cm from each other. Each plot consisted of 6 planting rows and one row without planting was considered among plots. Potatoes were planted in 4 to 5 cm holes in both years of the experiment at the end of March by a tuber machine. Soiling of the potato plants was also done 20 days after the potato seedlings sprouted.

3.3. Measured Traits

3.3.1. Leaf area index

To investigate changes in leaf area index during the growing season in six stages, three potato plants were selected from each plot considering the margin effect and the leaves area was calculated

using the LI-COR 3100 leaf area meter device. (Ahmadi *et al*., 2017).

3.3.2. Weed density and biomass dry weight

In order to measure the density of weeds, sampling was done in two stages (including 55 days after emergence and at the potato harvest stage) using two 1 m^2 quadrate in each plot. The number of weeds in each quadrate was counted and the samples were taken to the laboratory. The dry weight of weed biomass was also measured using a precision scale. In the ripening stage, about 110 days after planting and observing the signs of tuber ripening, with the use of 2 liters of paraquat poison per hectare, the aerial parts of dry potato plants and potato tubers were harvested from the middle 2 rows of each plot and the desired traits were measured.

3.3.3. Tuber yield

Potato tubers (about 12 plants) were harvested from the two middle planting rows of each plot, and their weight per surface unit was recorded in kilograms and converted to kilograms per hectare using the ratio (Orsaji and Tanha Khajeh, 2017). .

3.3.4. The number of tubers per plant

After harvesting potato tubers from middle 2 rows of each plot, the number of tubers per plant was counted.

3.3.5. Tuber diameter

To measure the tuber diameter, the largest diameter of the harvested tubers (12 plants) was measured by calipers in centimeters.

3.3.6. Tuber specific weight

The volume of 500 g samples of harvested tubers was determined by Archimedes method (volume of tubers in water) and specific weight of tubers was calculated by dividing weight of samples by volume (Eshagh beigi, 2010).

3.3.7. Harvest index

The harvest index was calculated by dividing the grain yield by the dry matter yield (Sobhani and Hamidi, 2015).

3.4. Statistical Analysis

The mean comparison of data was done using the LSD test at a 5% of probability level. In cases where the interaction effect was significant, standard error was used to compare the means.

4. RESULT AND DISCUSSION

4.1. *Leaf area index (LAI)*

The leaf area index in both Milva and Sante cultivars increased as days passed after planting. So that at the time of application of 400 ppm of auxin hormone (indole-3-acetic acid), the maximum leaf area index in the potato cultivars of Milva and Sante was 3.46 and 3.34, respectively, and at the time of application of 200 [ppm of auxin hormone (IAA)] leaf area index value was recorded as 3.18 and 3.07 respectively for Milva and Sante potato cultivars (Fig. 1 and 2). The highest value of the leaf area index in both cultivars studied was observed on the 65th to 70th day after greening. in the first decade of June, coinciding with the flowering of the plant, and after that, the value of the leaf area index decreased.

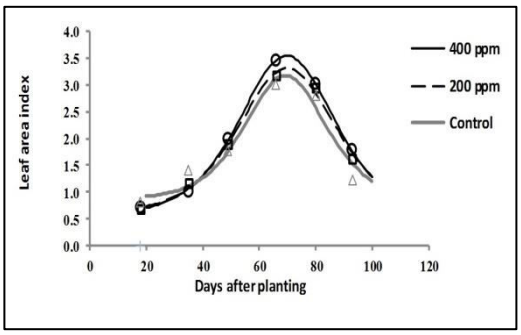

Fig. 1. The variation of leaf area index of milva cultivar influenced by IAA application during the growing season.

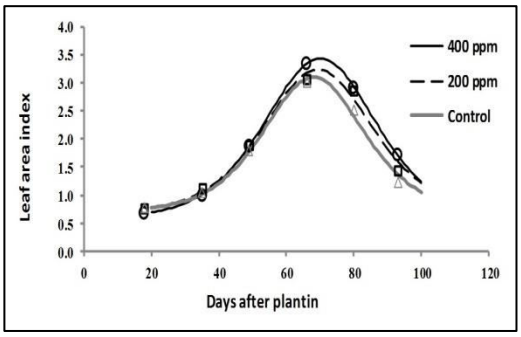

Fig. 2. The variation of leaf area index of sante cultivar influenced by IAA application during the growing season.

Examining the changes in the leaf area index during the season shows that the leaf area index of the two cultivars in different treatments of auxin hormone (IAA) follows a similar trend. At the beginning of the growing season, the amount of leaf production in the plant was slow, but with the increase in the vegetative growth of the plant, it increased its leaf more steeply. At the end of the growth period, a downward trend and changes in the leaf area index were observed. Leaf area index can lead to better absorption of light and thus more photosynthesis for the plant. Bangemann *et al*. (2014) also stated that increasing the leaf area index can lead to an increase in potato yield.

Rezvani Moghadam *et al*. (2009) observed in their study on the mixed cultivation of Mung bean and Black cumin that in some planting arrangements due to the higher leaf area index and as a result of receiving more light, the Mung bean plant grows better and was more efficient. Changes in the leaf area index among the weed control treatments showed that the highest value of the leaf area index was in the two-stage metribuzin treatment, followed by manual weeding and the pre-emergent application of metribuzin, and the lowest leaf area index value was in the control treatment without weed control (Fig. 3 and 4). Weed infestation during the potato growing season can lead to a significant reduction in the number and fresh weight of leaves in the potato plant (Khan *et al*., 2009). In a study (Shen *et al*., 2019) on the competitive effect of weeds on the growth characteristics of sweet potato, in the treatment of the absence of weeds, the highest value of leaf area index was obtained, which was consistent with results of this study.

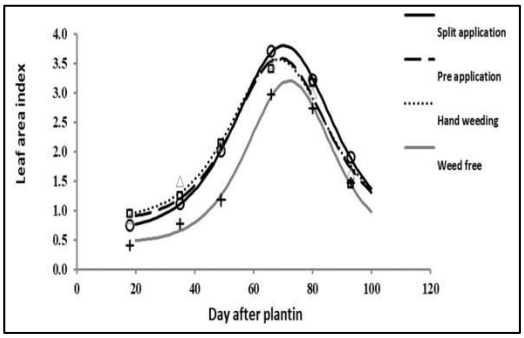

Fig. 3. Changes in the leaf area index of Milva potatoes under weed control treatments during the growing season.

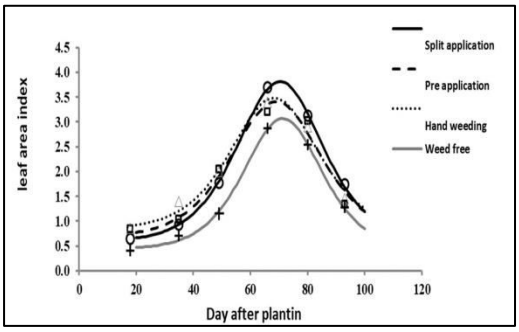

Fig. 4. Changes in the leaf area index of Sante potatoes under weed control treatments during the growing season.

4.2. *Number of tubers in the plant*

The results of analysis of variance showed that the effect of weed control was significant at 5% probability level on the number of tubers (Table 3). The highest and lowest number of tubers in the plant was obtained in the treatments using the two-step biozin herbicide by 7.77 and the treatment without weed control by 6.22 (Fig. 5).

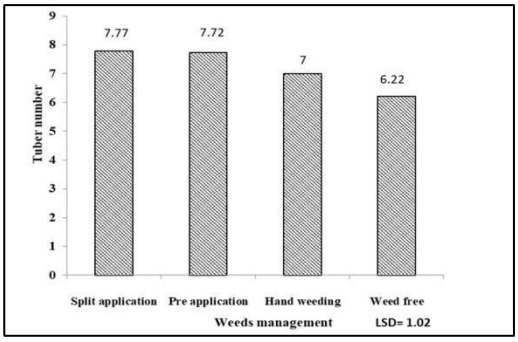

Fig. 5. The number of tubers in a potato plant in response to the concentration of effect weed control treatments. LSD 5% (LSD=1.02).

One of the important factors of increasing number of tubers in the plant is the use of different methods of weed management. Golzardi *et al*. (2007) was stated that the number of tubers per plant increases with the increase of weed control period. Weed competition reduces the number of potato tubers (Petroviene, 2002).

4.3. *Tube diameter*

The results of analysis of variance of the data showed that the potato tuber diameter was significantly influenced by the variety at the 1% probability level under the effect of auxin hormone application and weed control and at the 5% probability level (Table 3). Sante cultivar potato (with an average tuber diameter of 5.54 cm) produced larger tubers (7.35% increases) than Meliva cultivar with an average tuber diameter of 5.16 cm (Fig. 6). It seems that the Sante cultivar has been able to produce the highest tuber diameter by taking advantage of the environmental conditions because the difference in the tuber diameter depends on the cultivars using the growth and environmental conditions (Lemaga and Caesar, 1990) and these results confirm that the potential of different potato cultivars is different in such a way that one cultivar may show superiority for a number of traits compared to another cultivar, if it has a lower yield for another number of traits. Application of concentrations of 400 ppm of auxin hormone led to a significant increase in tuber diameter (20.57% increase compared to the control). This was despite the fact that no significant difference was observed between the treatments of 200 ppm of auxin hormone and the control (Fig. 7). Weed control also led to a significant increase in tuber diameter compared to the control treatment without weed control (Fig. 8).

Table 3. Result of combined analysis of variance of studied traits

S.O.V	df	tubers per plant	Diameter of tubers	Specific weight of tubers	Tuber yield	Dry biomass	Harvest index
Year (Y)	1	0.25 ^{ns}	0.000 ^{ns}	0.010 ^{ns}	5061750 ^{ns}	27861 ^{ns}	0.03 ^{ns}
block (Y)	4	12.45 ^{ns}	2.415 ^{ns}	0.119 ^{ns}	48394174 ^{ns}	195464 ^{ns}	0.02 ^{ns}
Cultivar (A)	1	12.25 ^{ns}	5.98 *	0.099 ^{ns}	33856 ^{ns}	1906471 ^{ns}	0.11 ^{ns}
A ×Y	1	0.25 ^{ns}	0.444 ^{ns}	0.000 ^{ns}	7000 ^{ns}	0.01 ns	0.01 ^{ns}
Error I	4	8.02	1.659	0.550	40463847	1419417	0.03
Auxin (B)	2	5.76 ^{ns}	17.454**	0.200 ns	881360776**	5636243**	0.08 ^{ns}
B×Y	2	0.77 ^{ns}	0.994 ^{ns}	0.002 ^{ns}	1270917 ^{ns}	6944 ^{ns}	0.01 ^{ns}
B ×A	2	0.65 ^{ns}	0.384 ^{ns}	0.035 ^{ns}	67533211 ^{ns}	191878 ^{ns}	0.01 ^{ns}
A × B × Y	2	0.77 ^{ns}	0.777 ^{ns}	0.007 ^{ns}	3798875 ^{ns}	20833 ^{ns}	0.01 ^{ns}
Weed control (C)	3	19.3*	30.109**	1.096**	1179080676**	16872498**	0.14*
C×Y	3	0.75 ^{ns}	0.890 ^{ns}	0.003 ^{ns}	1690639 ^{ns}	9269 ^{ns}	0.01 ^{ns}
C × A	3	1.42 ^{ns}	0.415 ^{ns}	0.019 ^{ns}	6478416 ^{ns}	227880 ^{ns}	0.02 ^{ns}
Y × C ×A	3	0.71 ^{ns}	0.740 ^{ns}	0.007 ^{ns}	3377074 ^{ns}	18519 ^{ns}	0.01 ^{ns}
C × B	6	2.48 ^{ns}	1.453 ^{ns}	0.091 ^{ns}	199622942*	1073958 ^{ns}	0.01 ns
Y × C ×B	6	0.88 ^{ns}	0.555 ^{ns}	0.006 ^{ns}	2955750 ^{ns}	16213 ^{ns}	0.00 ^{ns}
Y × C ×B	6	1.31 ^{ns}	0.298 ^{ns}	0.019 ^{ns}	15899171 ^{ns}	195375 ^{ns}	0.02 ^{ns}
C × Y× B ×A	6	0.79 ^{ns}	0.628 ^{ns}	0.004 ^{ns}	2113838 ^{ns}	11602 ^{ns}	0.01 ^{ns}
Error II	88	6.59	1.850	0.115	59070350	891484	0.05
C.V (%)	--	25.9	25.4	24.2	27.0	25.7	25.7

ns, * and ** : Non significant, significant at the 5 and 1 levels, respectively.

In this way, the two-step application of metribuzin, the pre-emergence application of metribuzen and manual weeding caused an increase in tuber diameter of 33.00, 30.71 and 29.94%, respectively, compared to the control treatment. However, no significant difference was observed between different weed control treatments.

4.4. *The tuber specific weight*

The results of analysis of variance of the data showed that the control of weeds on the specific weight of potato tuber was significant at the 1% of probability level (Table 3). The highest tuber specific weight in the treatments of metribuzin pre-emergent application, metribuzin two-stage application and manual weeding increased by 34.11, 32.97 and 26.98% respectively compared to the control without weed control (Fig. 9).

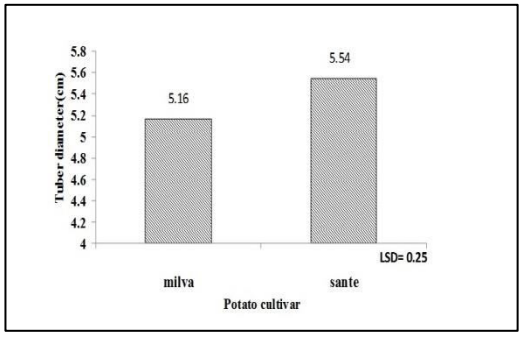

Fig. 6. The tuber diameter a potato plant in response to the concentration of cultivar , LSD 5%.

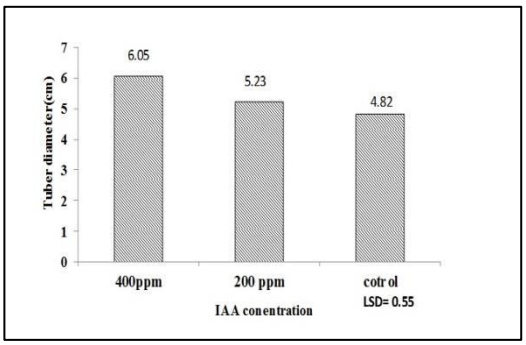

Fig. 7. The tuber diameter a potato plant in response to the concentration of IAA foliar application, LSD 5%.

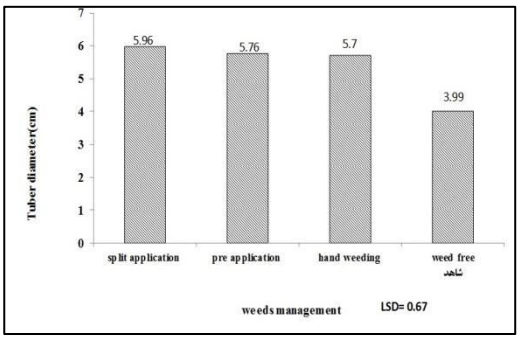

Fig. 8. The tuber diameter a potato plant in response to the concentration of weed control treatments, LSD 5%.

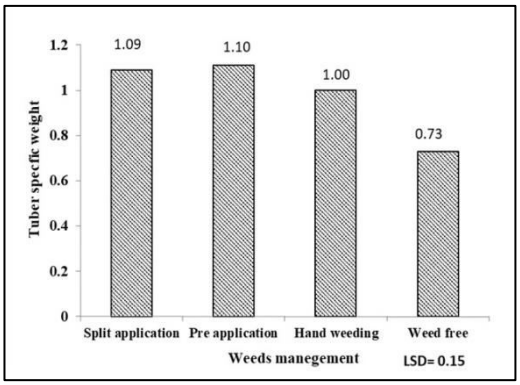

Fig. 9. The potato tuber specific weight in response to the concentration of weed control treatments, LSD 5%.

Specific weight is one of the criteria that can be used to determine the harvest time of potato tubers. Khajepour (2004) stated that when the specific weight of the potato tuber reaches 1.07 $gr.cm^{-3}$, the tuber can be considered mature. Improving soil moisture conditions can increase tuber specific gravity (Waddell *et al*., 1999). Weeds compete for growth resources, including water, so it seems that weed control can improve conditions. It brings better moisture to the potato plant and leads to an increase in the specific weight of tuber. During the application of auxin foliar spraying on the corn plant, it has been observed that auxin can turn the seed into a strong sink by stimulating growth and cell division, the result of which is an increase in acceptance of photosynthetic substances and the amount of dry matter in the seed (Zand *et al*., 2011).

4.5. *Tuber yield*

The effect of auxin hormone application and weed control at the 1% of probability level and the interaction effect of auxin hormone × weed control at the 5% of probability level on tuber yield of potato were significant (Table 3). The use of auxin hormone along with the use of weed management methods increased the tuber yield. This was despite the fact that the application of weed control did not show a clear increasing trend on yield. This situation shows that the application of auxin hormone can be useful when field weeds are controlled. Also, the use of weed control methods also increased the yield of potato tubers, among which the greatest increase was due to the two-step application of metyrbiozin, so that the most of these effects were observed in the application of 400 ppm of auxin hormone (Fig. 10).

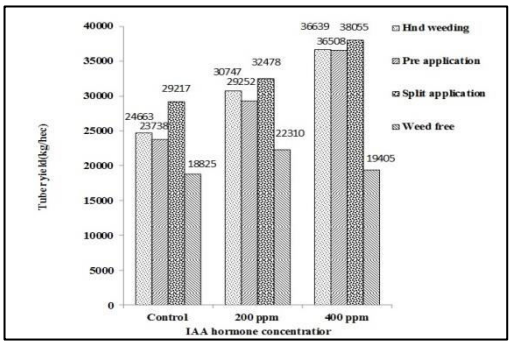

Fig. 10. The interaction effect of IAA hormone application and weed control on potato tuber yield.

The use of auxin hormone led to an increase in potato tuber yield. Like other plants, the growth, development and morphogenesis of potato is also under hormonal control (Kolachevskaya *et al*., 2019). Since most of the yield and yield components of potato, including the number of tubers, diameter of tubers, specific weight of tubers, yield of tubers, shoot biomass and weight of tubers are determined from the flowering stage onwards, and the presence of weeds can prevent the formation of and their bulking, in the pre-emergence application, metribuzin allows the product to do its primary growth without competing with weeds, therefore, the plant can have a proper growth and establishment at the beginning of the growing season. In addition, this herbicide with long-term effects in the soil has a better effect in controlling weeds (Fonseca *et al*., 2018). In addition, the post-emergence application of metribuzin in its two-step application treatment increased the efficiency of its effect and, as a result, created more positive effects on yield and yield components. In addition to the possibility of weed control at the beginning of the growing season, the two-step application of metribuzin can guarantee the subsequent control of weeds during the growing season to a large extent. It seems that for this reason, the yield and yield components of potato were at their maximum value in the treatment of the two-step application of metribuzin. The results of this study showed that in the absence of weed control, the characteristics of potato tuber did not benefit from the benefits of spraying the plant with IAA, and the presence of weeds led to a significant decrease in tuber yield and other tuber-related characteristics compared to other treatments were tested. In an experiment, Golzardi *et al.* (2006) found that by increasing the length of the weed control period, the final yield of potatoes increased, so that with the increase in the length of the weed control period, the yield of potatoes compared to the control treatment increased by 25.99%.

4.6. *Potato dry biomass*

Increasing the concentration of IAA in the weed control treatment led to an increase in dry biomass of potato. Also, the use of weed control methods increased the production of potato biomass. The greatest increase in biomass was related to the two-stage treatment of Metribiozin (Fig. 11). The application of IAA increased the dry weight of potato shoot biomass. Plant hormones significantly affect the yield and quality characteristics of crops (Wierzbowska *et al*., 2016). Auxin is among the hormones that are effective in stimulating cell division and growth of plant tissues (Naeem *et al*., 2004).

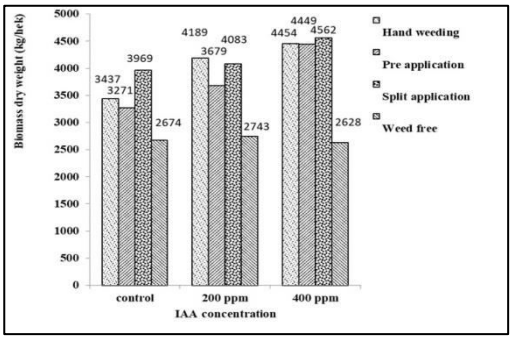

Fig. 11. The interaction effect of IAA hormone application and weed control on potato tuber yield.

Hamidi *et al.* (2014) stated that foliar spraying with auxin caused a significant increase in the dry weight of Grana variety of potato aerial organs. In the study of Kaya *et al*. (2013), an increase in corn growth was observed under the influence of auxin treatments. Weed control led to an increase in potato shoot biomass. Potato does not have a high competitive power against weeds, also this plant is cultivated in rows, which is a result of the presence of empty space, the possibility of the presence, competition and negative effects of weeds in this plant is very likely (Rashed Moshele and colleagues, 1390). Weed infestation affects the growth and physiological traits of potato plants, and the competition between the crop and weeds for water, nutrients, light, and carbon dioxide, as well as allelopathy, reduces the quantitative and qualitative yield of the crop (Zimdahl, 2007). Mondani *et al*. (2011), in an experiment expressed that interference of weeds with potato plants caused a decrease in dry matter accumulation, leaf area index and crop growth rate compared to the treatment without weeds. Potato growth was affected by the competition with weeds. The critical period of weed control for Narkota variety potato is estimated from 10 to 24 days after emergence, during which the field must be weed-free so that the reduction in production does not exceed 5% (Hutchinson, 2014). For this reason, weed control is one of the critical management activities in the direction of high-yielding potato production. To control weeds, mechanical methods or herbicide application can be used, which is the usual chemical method (Zimdahl, 2007). The use of herbicides can significantly reduce weed damage (Oerke, 2006).

4.7. *Harvest index*

The effect of weed control on harvest index was significant at 5% probability level (Table 3). In the two-step application, metribuzin pre-emergent application and weeding, an increase of 15.24, 14.10 and 8.42 percent of harvest index was observed (Fig. 12).

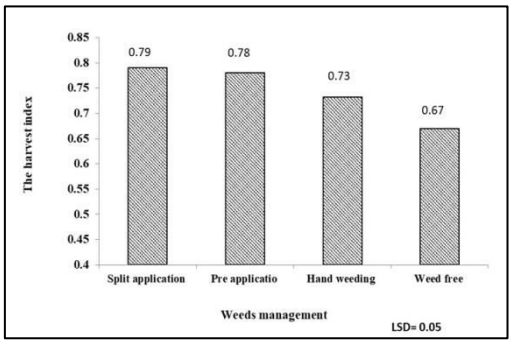

Fig. 12. The harvest index potato plant in response to the concentration of weed control treatments, LSD 5%.

The highest harvest index was observed at 400 ppm auxin concentration and then at 200 ppm auxin concentration. In the experiment of Hamidi *et al*. (2014), the use of auxin led to an increase in the

harvest index compared to the control treatment without growth regulator. In addition, due to the sensitivity of potato in the competition with weeds, the highest harvest index was observed in the weed control treatments.

5. CONCLUSION

The effect of auxin application and the use of weed control methods had a significant effect on other potato traits, except dry matter percentage. The maximum values of tuber diameter, tuber specific weight, shoot biomass, harvest index, tuber yield were observed under 400 ppm IAA. In addition, weed control also led to an increase in the values of the mentioned traits compared to the control treatment without control. Comparison of interaction effect of IAA application and weed management showed that in the absence of weed control, IAA application was not affect on important traits such as tuber yield and biomass production, because IAA application, without weed control with the positive effect on the growth of weeds has increased the competitive power of weeds. In general, the comparison between the tested cultivars also showed that the biomass of aerial parts in Milva cultivar was more than that of Sante cultivar and the tuber size in Sante cultivar was more than that of Milva cultivar. However, no significant difference was observed in terms of tuber yield among the cultivars studied. Screening of leaf area index and dry matter accumulation in both Milva and Sante cultivars during the growing season showed that the maximum leaf area index of both Milva and Sante cultivars was observed under 400 ppm of IAA. Auxin hormone can lead to an increase in leaf area index, which leads to better absorption of light and thus more photosynthesis for the plant. In fact, increasing the leaf area index can lead to an increase in potato yield, which was evident in the obtained results. Based on the obtained results, it can be generally stated that the use of plant growth regulators including IAA can have beneficial effects on potato growth, yield and quality. However, the control of field conditions, including weeds, can play a key role in the effectiveness or ineffectiveness of the use of plant hormones. Therefore, it is recommended that if plant hormones are used in order to benefit from their positive effects on potatoes, the control of weeds in the field must be taken into consideration.

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FOOTNOTES

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