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Evaluation of Integrated Nutrition on Quantitative and Qualitative Yield of Asparagus (*Asparagus officinalis* L.) Cultivars in Dezful

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ABSTRACT

BACKGROUND: Asparagus is a perennial crop that is well-suited for small-scale and part-time farming operations, and it is considered a healthy food with a high content of bioactive compounds.
OBJECTIVES: This study was conducted to investigate the effect of different fertilizer treatments on the yield and agricultural characteristics of various cultivars of Asparagus plants at Safi Abad Dezful Agricultural Research.
METHODS: The experiment was done as a split-plot design based on completely randomized block design with three replications. The main factor consisted of three cultivars of asparagus (Mary Washington, Linda and Mike), while the sub-factor included five fertilizer levels (1-Manure fertilizer, 2-Basic chemical fertilizers + manure fertilizer, 3- Basic chemical fertilizers + manure fertilizer + sulfur, 4- Basic chemical fertilizers + manure fertilizer + calcium and 5- Basic chemical fertilizers + manure fertilizer + calcium + sulfur).
RESULT: The results indicated significant effects of both cultivar and fertilizer treatment on the fresh and dry yield of the edible stem and the daily growth of the stem. Furthermore, the interaction between cultivar and fertilizer had a significant effect on fresh and dry yield of the edible stem, stem daily growth, amount of nitrogen and protein percentage. The study revealed a significant variation between the different asparagus cultivars and fertilizer treatments concerning the measured traits. Specifically, the Mary Washington cultivar exhibited the highest number of stems per plant (14.8), while Mike cultivar had greatest stem diameter (11.2 mm). The usage of manure fertilizer along with chemical fertilizers, sulfur, and calcium in the Mary Washington cultivar resulted in the highest yields of edible and dry stems, measuring 2758 and 665 $kg.ha^{-1}$, respectively. Moreover, results demonstrated that simultaneous application of manure fertilizer and basic chemical fertilizers led to the highest nitrogen content (7.41%) and protein content (46.25%) in the Linda cultivar.
CONCLUSION: Based on the findings of this research, for achieving the highest yield of edible and dry stems in asparagus plants in the Dezful region, it is recommended to choose the Linda cultivar and apply a combination of manure fertilizer with chemical fertilizers, sulfur, and calcium.

KEYWORDS: *Calcium, Manure fertilizer, Nitrogen, Protein, Sulfur.*

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1. BACKGROUND

Asparagus is an herbaceous, perennial, bipedal plant with an herbaceous, cylindrical, standing stem that reaches 100-150 cm in height. Asparagus produces two types of stems, a relatively thick vegetative stem called a spear, which grows from the rhizome and forms the edible part of the plant. The edible part of asparagus for nutrition is the leaf buds under the soil surface, which, as the length increases, these buds change into an organ called a spire or a false stem (Hasandokht *et al*., 2017). Currently, the biggest challenge that the world is facing is the increase in population and the demand for food. The ability of natural resources to meet the needs of population growth is a fundamental issue for international societies, and due to factors such as competition and intense demand from industries and cities, these resources are destroyed and polluted, and as a result, severe pressure is placed on natural resources. Therefore, increasing the area under cultivation in the future will not be a good solution. Researchers consider increasing productivity along with production sustainability to be the most effective way to meet future food needs (Moridian, 2019). Today, a large amount of nitrogen, potash and phosphate chemical fertilizers are used as basic chemical fertilizers to feed crops, which in addition to destroying the environment, brings many risks to humans. Long-term studies have shown that the excessive use of chemical fertilizers reduces the yield of crops; this decrease in yield is the result of soil acidification, reduction of soil biological activities, loss of soil physical properties and the absence of micro nutrients in nitrogen, phosphorus and potassium fertilizers (Sabahi, 2006). In intensive farming systems, organic materials and soil nutrients are quickly depleted, for this reason, it is necessary to use new scientific methods to meet the ever-increasing needs of the growing population. Therefore, in order to achieve optimal yield, there is a need to replace nutrients. Based on this, the management of agricultural systems should be seriously revised and new systems should be designed, whose priority is long-term stability and, at the same time, maintaining production in the short term. Among these new scientific methods is ecological agriculture, which is an integrated agricultural system based on ecological principles, in which the quality of products is more important than their quantity (Moridian, 2019). In this regard, organic fertilizers and especially manure fertilizers play an important role in sustainable agriculture by providing nutrients needed by plants. In addition to providing nutrients needed by plants, organic fertilizers maintain plant health and improve the physical and chemical characteristics of soil (Tohidi Moghadam *et al*., 2016). Long-term experiments in fixed plots of combined use of organic and chemical fertilizers showed the greatest increase in the amount of soil organic carbon compared to the use of each of the organic and chemical fertilizers alone. The use of organic fertilizers with their effect on soil stability and self-regulation should be considered. Organic fertilizers have an effect on the quantity and quality of carbon and soil capacity in storing and releasing nutrients needed for plant growth during the process of decomposition and mineralization. The use of organic fertilizers is more effective in maintaining the structure of the soil and increasing its quality than directly helping to increase the yield of crops (Alipoor Miandehi *et al*., 2013). Therefore, to reduce the economic and environmental problems caused by the excessive use of chemical fertilizers, the use of organic fertilizers has been suggested, so that in addition to reducing the use of chemical fertilizers, the efficiency of used chemical fertilizers can also increase (Fallahi *et al*., 2009).

2. OBJECTIVES

This research was conducted with the aim of investigating the effects of integrated nutrition on quantitative and qualitative traits of asparagus plant in Safi Abad Dezful Research Center.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This study was done to assess effect of different fertilizer treatments on yield and agricultural characteristics of various cultivars of Asparagus plants at Safi Abad Dezful Agricultural Research. The experiment was conducted as a split-plot design based on completely randomized block design with three replications. The main factor consisted of three cultivars of asparagus (Mary Washington (C_1), Linda (C_2) and Mike (C_3)), while the sub-factor included five fertilizer levels (1-Manure fertilizer (a), 2-Basic chemical fertilizers (b) + manure fertilizer, 3- Basic chemical fertilizers + manure fertilizer + sulfur (c), 4- Basic chemical fertilizers + manure fertilizer + calcium (d) and 5- Basic chemical fertilizers + manure fertilizer + calcium + sulfur (e)).

3.2. Farm Management

To assess the physical and chemical characteristics of the experimental field's soil, soil samples were collected from a depth of 0 to 30 cm. After creating a composite sample, the desired properties were analyzed in the soil science laboratory. The pH and salinity of the soil were found to be 7.3 and 2.3 ds/m, respectively. The carbon content in the soil was measured to be 0.76, while the levels of potassium and phosphorus were determined to be 209 and 13.6 ppm, respectively. At the beginning of the experiment, asparagus plants were transferred from the nursery to the main field and planted in pits with a row spacing of 90 cm. The distance between plants within each row was 25 cm. After one month of cultivation, the process of soiling and changing the atmosphere began, and the soil from the piles was transferred to the bottom of the fields. In early February of the following year, after removing the dry aerial parts of asparagus, which had withered due to the cold weather, the desired fertilizers were applied to all the plots. Nitrogen-based fertilizer was applied at a rate of 75 $kg.ha^{-1}$, phosphate fertilizer at a rate of 75 $kg.ha^{-1}$, and potash at a rate of 75 $kg.ha^{-1}$. Additionally, sulfur and calcium were used at a rate of 25 $kg.ha^{-1}$. Edible asparagus stems began to grow from the 8th of February, and as temperatures increased, harvesting was conducted every two to four days. Harvesting was done by carefully observing stems with a height of 18 to 20 cm, using a special knife to cut the stems at a depth of two centimeters under the soil, exactly beneath the same stem, and with a slow movement to avoid any damage. The harvesting period lasted for 8 weeks in the spring season, from March 1st to April 30th.

3.3. Measured Traits

3.3.1. *Number of stems per plant*

To measure this trait, ten crop were randomly selected from each plot and average number of stems was calculated to determine number of stems per plant.

3.3.2. *Stem diameter*

For this purpose, ten plants were randomly selected from each plot, and the average stem diameter was measured using calipers.

3.3.3. *Fresh and dry yields of edible stems*

After applying the experimental treatments, stems were harvested from an area equivalent to one square meter in each plot. The fresh weight of the stems was measured and recorded. Then, samples were taken and dried to determine their dry weight. This process allowed for the calculation of the fresh (wet) and dry yield of edible stems in each plot (Mousavizadeh *et al*., 2019).

3.3.4. *Measuring the amount of nitrogen and protein*

The nitrogen content in the plant samples was determined using the Kjeldahl method. For this purpose, 0.2 grams of the plant sample was weighed and then digested with sulfuric acid. The nitrogen content was measured using a Kjeldahl Analyzer unit. Based on the nitrogen content, the percentage of protein in the samples was calculated.

3.4. Statistical Analysis

After data collection, the analysis of variance was performed using SAS (Ver. 9.1, SAS Institute, Cary, NC, USA), and mean comparison was conducted using Duncan's test at the 1% and 5% probability levels. Graphs were also created using Excel software.

4. RESULT AND DISCUSSION

4.1. *Stem daily growth*

Based on the results of analysis of variance, the difference between the cultivars and the effect of using different fertilizers and the interaction effect of the treatments were significant in terms of the effect on the daily growth of the stem (Table 1). The daily growth rate of the stem in the time range measured in all fertilizer levels in the Linda cultivar was higher than other cultivars, so that in this cultivar, the treatments of using manure fertilizer along with chemical fertilizers and sulfur and calcium, as well as the application of manure fertilizer alone, had the highest daily growth rate (with an average of 11.33 and 11 cm, respectively). The lowest daily growth rate of stem with an average of (4.66cm) was observed in the treatment of application of manure fertilizer, basic chemical fertilizer + calcium and in Mike cultivar. In this study, the application of calcium along with sulfur as well as manure fertilizer and basic chemical fertilizers led to an increase in the yield of fresh and dry stem yield and also to an increase in the daily growth rate of stems, especially in the Linda cultivar (Fig. 1). The higher stem daily growth in the Linda cultivar was related to the genetic characteristics of this cultivar and its better response to the use of fertilizers. The growth conditions for Mary Washington and Mike cultivars were almost similar, but the Mike cultivar showed a better response to the simultaneous application of chemical fertilizer, manure fertilizer + sulfur and calcium.

Table 1. Result analysis of variance the effect of treatment on studied traits

S.O.V	df	Fresh yield of stem	Dry matter yield	No. stems per plant	Nitrogen percentage
Replication (R)	2	497342	5488	6.48	0.83
Cultivar (V)	2	26201980**	274404**	593**	0.2 ns
Error (a)	4	444065	4469	3. 2	0.67
Fertilizer (F)	4	3030297**	48134**	7.7*	5.96**
V×F	8	1388672**	8452**	5.3ns	0.71*
Error (b)	24	179756	11.08	4.1	0.25
CV (%)	-	13.22	13.5	16	8.69

ns, * and **: Not–significant and significant at 0.05 and 0.01 probability levels, respectively.

Continue table 1.

S.O.V	df	Stem diameter	Stem daily growth	Protein percentage
Replication (R)	2	26.7	5.48	24.24
Cultivar (V)	2	125**	101**	11.79 ns
Error (a)	4	0.53	0.75	32.07
Fertilizer (F)	4	1.49 ns	6.5**	255**
V×F	8	2.12*	4.1*	25.7 ns
Error (b)	24	3	1.26	9.73
CV (%)	-	18.23	14.21	8.55

ns, * and **: Not–significant and significant at 0.05 and 0.01 probability levels, respectively.

4.2. *Dry matter yield*

Linda, Mary Washington, and Mike cultivars had the highest dry yield in all fertilizer levels, respectively, and the use of manure fertilizer along with chemical fertilizers, sulfur, and calcium in Linda cultivar had the highest dry yield (665 $kg.ha^{-1}$), and from this point of view, with other treatments had significant differences. The lowest dry matter yield (173$kg.ha^{-1}$) belonged to the Mike cultivar and the sole application of manure fertilizer (Fig. 2). Abdel Gawad *et al.* (2019) stated increase in the green cover due to the use of basic chemical fertilizers, especially nitrogen, and as a result, the increase in the amount of radiation and materialization, were cited as the main reasons for the increase in the production and accumulation of dry matter and the increase in the plant biomass.

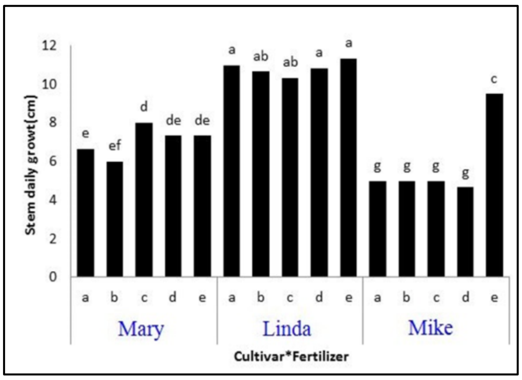

Fig. 1. Interaction effect of cultivar and fertilizer on stem daily growth. Mean which have at least once common letter are not significant different at 5% probability level by (DMRT). a: manure fertilizer, b: basic chemical fertilizers + manure fertilizer, c: basic chemical fertilizers + manure fertilizer + sulfur, d: Basic chemical fertilizers + manure fertilizer + calcium e: basic chemical fertilizers + manure fertilizer + calcium + sulfur.

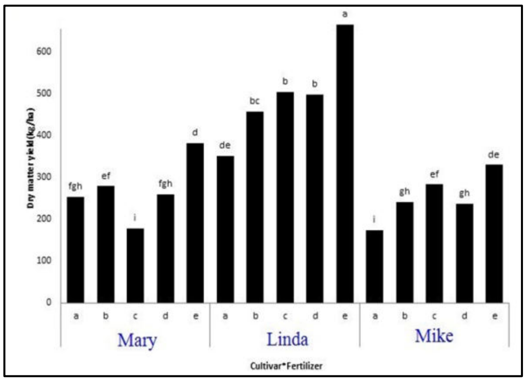

Fig. 2. Interaction effect of cultivar and fertilizer on dry matter yield. Mean which have at least once common letter are not significant different at 5% probability level by (DMRT). a: manure fertilizer, b: basic chemical fertilizers + manure fertilizer, c: basic chemical fertilizers + manure fertilizer + sulfur, d: Basic chemical fertilizers + manure fertilizer + calcium e: basic chemical fertilizers + manure fertilizer + calcium + sulfur.

Arazmjo *et al*. (2010) stated that the application of chemical fertilizers has the greatest effect on increasing the amount of photosynthetic pigments in the plant and increase in pigments leads to an increase in the amount of material production and as a result, an increase in the accumulation of dry matter , fresh and dry yield of edible stem. Also, Cassman *et al*. (2017) pointed out the relationship between the use of basic chemical fertilizers and the increase in the amount of photosynthetic pigments in the plant and stated that this increase in the amount of pigments has an important effect in increasing the rate of materialization and accumulation of dry matter. In general, the simultaneous application of chemical and manure fertilizers, along with calcium and sulfur, has led to an increase in nitrogen content in the plant. This increase has also resulted in higher levels of chlorophylls and carotenoids, which contribute to enhanced greenness, better sunlight absorption, increased production of photosynthetic substances, and ultimately improved growth and dry matter yield in asparagus. According to Fageria (1992), a significant portion of the dry matter produced by plants is a result of photosynthesis. Therefore, increasing the chlorophyll content in leaves through enhanced photosynthesis and greater production of dry matter can be instrumental in improving the overall dry matter yield.

4.3. *The fresh yield of the edible stem*

The mean comparisons of interaction effects of treatments showed that the Linda cultivar was superior to the other cultivars in terms of the fresh yield of the edible stem. Mary Washington cultivar had the lowest fresh yield of edible stem at different fertilizer levels. In all cultivars of Asparagus, the simultaneous application of manure fertilizer, chemical fertilizer, sulfur and calcium was superior to the application of manure and other treatment compounds alone, so that the treatment of application of manure along with chemical fertilizer, sulfur and calcium in the Linda cultivar has the highest fresh yield. The edible stem was (6677 $kg.ha^{-1}$), which was superior to other experimental treatments. Although in all fertilizer levels, the Mary Washington variety had the lowest yield of edible stems, but the use of manure fertilizer along with chemical fertilizers, sulfur and calcium in this cultivar resulted in the highest yield of edible stems (with an average of 2758 $kg.ha^{-1}$). Also, among the experimental treatments, the lowest yield of edible stems was 1894 $kg.ha^{-1}$ in the application of manure fertilizer along with chemical fertilizer and sulfur in Mary Washington cultivar (Fig. 3). According to the report of Roustaei *et al*. (2009) the use of organic fertilizers in combination with chemical fertilizers increased growth and accumulation of dry matter in corn. The reason for this situation is the better and timelier supply of nutrients needed by the plant, especially nitrogen (which is needed in all stages of plant growth). Nitrogen increases the durability of the leaf surface, increases the photosynthetic materials during the growth period of the plant, and causes an increase in the number of branches and their final volume, which ultimately increases the amount of dry matter. Lenardis *et al*. (2016) reported an increase in the rate of vegetative growth and as a result an increase in the fresh and dry yield of edible stems in coriander plants with the application of basic chemical fertilizers, which was consistent with the results of this research.

4.4. *Number of stems per plant*

There was a significant difference between the studied cultivars in terms of the number of stems per plant (Table 1). Mary Washington cultivar had the highest number of stems per plant (with an average of 14.8 stems), and after this cultivar, Linda cultivar had more stems per plant (5.13 stems per plant). Also, the results showed that Mike cultivar had the lowest number of stems per plant (with 3 stems per plant) (Fig. 4). Mary Washington cultivar had more stems per plant, so that compared to Linda and Mike cultivars; it formed 65 and 79% more stems per plant, respectively. The change in number of stems per plant in the Asparagus plant is dependent on the change in the Plant growth parameters, which ultimately affects vegetative growth and the number of stems per plant. Factors influencing plant growth can be categorized into two groups: genetic and environmental. Environmental factors have a significant impact on quantity and quality of plant growth as well as their distribution.

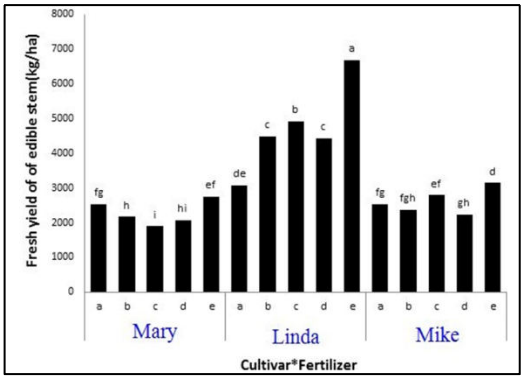

Fig. 3. Interaction effect of cultivar and fertilizer on fresh yield of edible stem. Mean which have at least once common letter are not significant different at the 5% level using (DMRT). a: manure fertilizer, b: basic chemical fertilizers + manure fertilizer, c: basic chemical fertilizers + manure fertilizer + sulfur, d: Basic chemical fertilizers + manure fertilizer + calcium e: basic chemical fertilizers + manure fertilizer + calcium + sulfur.

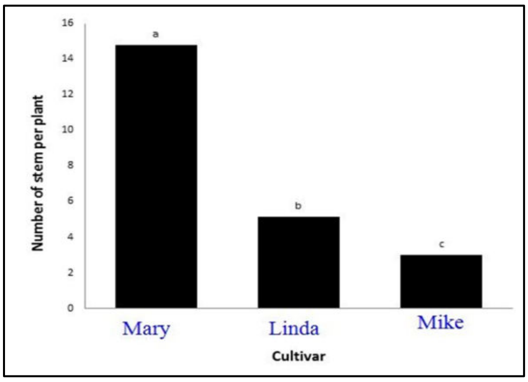

Fig. 4. Effect of cultivar on number of stem per plant. Mean which have at least once common letter are not significant different at 5% probability level by (DMRT). a: manure fertilizer, b: basic chemical fertilizers + manure fertilizer, c: basic chemical fertilizers + manure fertilizer + sulfur, d: Basic chemical fertilizers + manure fertilizer + calcium e: basic chemical fertilizers + manure fertilizer + calcium + sulfur.

Among the most crucial environmental factors are ambient temperature, humidity, altitude above sea level, and soil characteristics. However, it should be noted that even under similar environmental and nutritional conditions, one of the most critical determinants of the plant's growth rate is the genetic characteristics of the cultivar (Mousavizadeh *et al*., 2019).

4.5. *Stem diameter*

Among the three cultivars of Asparagus, the Mike cultivar had the largest stem diameter (10.46 mm) and in this respect, there was no significant difference with the Linda cultivar (10.2 mm). Also, the results showed that Mary Washington cultivar had a diameter equal to 5.33 mm, which was the smallest stem diameter, and in this respect, it was significantly different from Mike and Linda cultivars (Fig. 5).

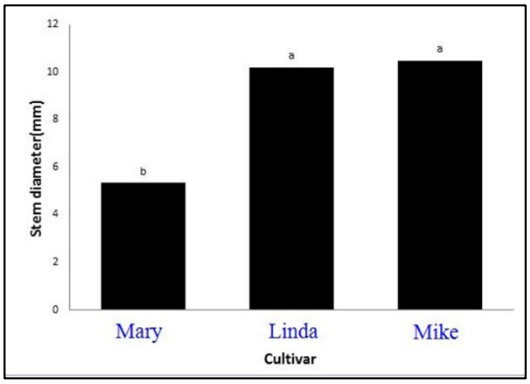

Fig. 5. Effect of cultivar on stem diameter. Mean which have at least once common letter are not significant different at 5% probability level by (DMRT). a: manure fertilizer, b: basic chemical fertilizers + manure fertilizer, c: basic chemical fertilizers + manure fertilizer + sulfur, d: Basic chemical fertilizers + manure fertilizer + calcium e: basic chemical fertilizers + manure fertilizer + calcium + sulfur.

The increase in the diameter of the stem in the Mike cultivar compared to the other cultivars can be due to the genetic characteristics of the cultivar, such as the ability of the cultivar to absorb nutrient from the soil, which can be effective on the growth and, as a result, the diameter of the stems in different cultivars. The number of stems in a plant relative to the diameter of the stem often follows a similar pattern in different cultivars. The plant's genetic conditions play a key role in determining the number of stems it produces. When there are more stems, the diameter of the stems tends to be smaller, which is attributed to increased intra-plant competition for resources. In the case of the Mike and Linda cultivars, which formed fewer stems per plant, there was less competition for resources within the plant, leading to larger stem diameters compared to the Mary cultivar. However, the fertilizer treatments did not have a significant effect on the number of stems in the cultivars (Table 1).

4.6. *Nitrogen percentage*

The percentage of nitrogen in different cultivars of Asparagus was affected by fertilizer treatments and the results showed that in cultivars of Mike and Mary Washington, the simultaneous use of manure fertilizer, basic chemical fertilizers and sulfur had a greater effect on the nitrogen percentage, while in the cultivar of Linda, the simultaneous use of manure fertilizer and basic chemical fertilizers had a greater effect on increasing the nitrogen percentage. The simultaneous application of manure fertilizer and basic chemical fertilizers resulted in the highest nitrogen percentage of 7.41% in Linda cultivar. Also, in Mary Washington and Mike cultivars, the highest percentage of nitrogen was obtained (7.23 and 6.68%, respectively), in the simultaneous application of manure fertilizer, basic chemical fertilizers and sulfur (Fig. 6).

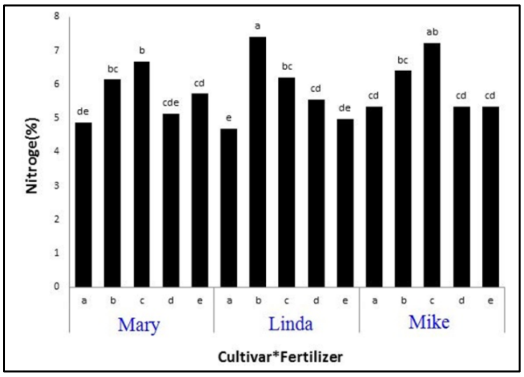

Fig. 6. Interaction effect of cultivar and fertilizer on nitrogen percentage. Mean which have at least once common letter are not significant different at 5% probability level by (DMRT). a: manure fertilizer, b: basic chemical fertilizers + manure fertilizer, c: basic chemical fertilizers + manure fertilizer + sulfur, d: Basic chemical fertilizers + manure fertilizer + calcium e: basic chemical fertilizers + manure fertilizer + calcium + sulfur.

4.7. *Protein percentage*

Asparagus protein percentage was affected by cultivar and fertilizer treatments (Table 1). The percentage of protein in Mike and Mary Washington cultivars increased significantly with the simultaneous application of manure fertilizer, basic chemical fertilizers and sulfur, while in the Linda cultivar, the simultaneous application of manure fertilizer and basic chemical fertilizers had a greater effect on increasing the protein percentage (Fig. 7).

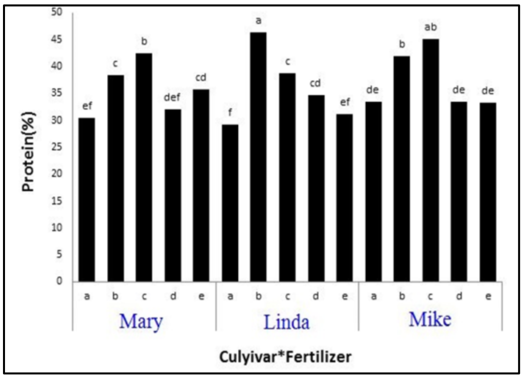

Fig. 7. Interaction effect of cultivar and fertilizer on protein percentage. Mean which have at least once common letter are not significant different at the 5% probability level by (DMRT). a: manure fertilizer, b: basic chemical fertilizers + manure fertilizer, c: basic chemical fertilizers + manure fertilizer + sulfur, d: Basic chemical fertilizers + manure fertilizer + calcium e: basic chemical fertilizers + manure fertilizer + calcium + sulfur.

The highest protein percentage (with an average of 46.25%) was obtained in the application of manure fertilizer and basic chemical fertilizers, and this treatment had a significant statistical difference with other treatments. Also, according to these results, it was found that the lowest percentage of protein among all experimental treatments was 28.29% belonging to the application of manure fertilizer in Linda cultivar (Fig. 7). The percentage of protein depends on the percentage of nitrogen in the plant, and the treatments that lead to an increase in the amount of nitrogen also increase the percentage of protein. The increase in protein percentage due to the use of manure fertilizers along with chemical fertilizers was more than other treatments. In contrast, the integrated use of calcium and sulfur in combination with animal and chemical fertilizers reduced the amount of protein. Application of sulfur alone with manure and chemical fertilizers in Mike and Mary Washington cultivars increased the percentage of protein to a greater extent, but in Linda cultivar, the amount of protein in this treatment was lower than the application of manure fertilizer along with basic chemical fertilizers. Shariati Nia *et al*. (2016) stated that the use of manure and chemical fertilizers leads to an increase in the amount of protein production in the plant due to the availability of nitrogen required by the plant, and as a result, the percentage of protein also increases. However, in many studies, an increase in protein percentage has been reported by increasing the use of chemical and organic fertilizers containing nitrogen (Pawar *et al*., 2013), which confirm the results of this study. Roshan Zamir *et al*. (2005) also reported an increase in the amount of protein due to the use of manure fertilizer, which confirms the results of this study. Nasiri *et al*. (2020) stated that different fertilizer treatments resulted in obtaining different amounts of protein in the plant, so that the fertilizers that contained higher amounts of chemical or organic nitrogen also had a higher percentage of protein. Sharifi and Amiryusefi (2017) also stated that the combination of fertilizers may lead to an increase in the percentage of protein in the plant with a positive effect on nitrogen absorption by the plant, which was consistent with the findings of this study. In the present study, although the response of each cultivar to different fertilizer treatments was different, the results showed that the combination of chemical fertilizers with manure fertilizers, especially with the use of sulfur in Mary Washington cultivar and calcium in the Mike cultivar, and the use of only manure and chemical fertilizers in Linda cultivar led to a greater increase in protein percentage, which indicated the difference in the reaction of each cultivar to the application of different sources of fertilizer in terms of plant protein percentage. According to the researchers, since amino acids are the structural unit of proteins and due to the essential role of nitrogen in the structure of amino acids, the use of nitrogen-providing fertilizers such as manure fertilizer and basic chemical fertilizers increases the amount of nitrogen in the soil for the plant and as a result increases seed protein (Sharifi and Amiryusefi, 2017). The use of sulfur along with manure and chemical fertilizers had a positive effect on the amount of protein in Asparagus, and this positive effect of sulfur may be due to its effect on the protein-forming amino acids. The lack of sulfur-containing amino acids is the most important factor limiting the biological value of protein. The decrease in the amount of protein in sulfur-deficient plants is correlated with the preferential production of proteins, so that in these plants the amount of amino acids methionine and cysteine is lower and the amount of other amino acids such as arginine and aspartic acid is higher. The low amount of sulfur in proteins has a great effect on their nutritional quality (Ghaderi *et al*., 2017). Mostafavi-Rad *et al*. (2019) also reported that sulfur is part of the structure of the amino acids cysteine and methionine and, as a result, is part of the structure of proteins. Both of these amino acids are necessary for the production of other sulfur-containing compounds, such as co-enzymes and secondary plant products. In this study, there was a difference between different Asparagus cultivars in terms of protein percentage at different fertilizer levels, which could be due to the genetic differences of the cultivars as well as the difference in their ability to utilize resources. In the study of Safaee (2013) a difference was observed between the protein percentages of safflower cultivars, which pointed to similar reasons in this case. In the study of Nasiri *et al*. (2020) there was a difference between different wheat cultivars in terms of grain protein percentage, and these researchers attributed some of these changes to the difference in the ability of the cultivars to absorb nutrients, especially nitrogen, from the soil, which is the building block of protein. It can play a decisive role in protein synthesis and its accumulation in the plant.

5. CONCLUSION

The variation in growth rate and final yield among cultivars can be attributed to genetic factors or the ability of cultivars to efficiently utilize environmental resources. In this study, significant differences were observed among different Asparagus cultivars in terms of growth characteristics, element absorption and their storage in aerial organs. Specifically, the Linda cultivar exhibited the highest fresh and dry yield of edible stems, surpassing other cultivars in this regard. Based on the findings, the different fertilizer treatments had a significant impact on the growth rate, fresh and dry yield of edible stems and the amount of elements present in the aerial parts of the asparagus plant. The accumulation of elements in the aerial organs showed notable variations among cultivars and different fertilizer levels. Specifically, the simultaneous application of manure fertilizer and basic chemical fertilizers resulted in the highest nitrogen and protein content in the Linda cultivar. These results highlight the importance of fertilizer management in optimizing the growth and nutritional qualities of asparagus plants. Considering the highest fresh and dry yield of edible stems observed in the Linda cultivar with the simultaneous application of manure fertilizer and chemical fertilizers, sulfur, and calcium, this treatment is recommended for asparagus cultivation in the Dezful region. On the other hand, if the aim is to improve the quality characteristics of the asparagus plant, such as increasing protein content, the simultaneous application of manure fertilizer and basic chemical fertilizers can be used. By customizing fertilizer treatments based on specific objectives, farmers can effectively enhance both the yield and quality of their asparagus crops in the Dezful region. Properly managing the application of fertilizers, along with other agricultural practices, plays a crucial role in achieving successful and sustainable asparagus cultivation in the area. This approach enables farmers to maximize productivity and produce high-quality asparagus that meets market demands, ensuring economic viability in the region.

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FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

CONFLICT OF INTEREST: Authors declared no conflict of interest.

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