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Effects of Leonardite Application on Yield of Broad Beans (*Vicia faba* L.) under Low Input Rainfed Semi-arid Mediterranean Highland Condition of Turkey

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ABSTRACT

Background: This study was conducted to determine the effects of different doses of leonardite applications on yield and some yield components of spring grown broad beans (*Vicia faba* L.) in the ecological conditions of Siirt province in 2017 and 2019 in the experimental fields of Siirt University.

Methods: The study was established in a randomized complete block design with three replications. Tested leonardite doses were 0, 200, 400, 600, 800 and 1000 kg ha^{-1}.

Conclusion: The effect of leonardite doses on all of the investigated properties was found statistically significant. According to the results, plant height, first pod height, number of pods per plant, number of seeds per pod, 100 grain weight and grain yields were varied between 45.7-61.3 cm, 10.1-13.2 cm, 5.03-8.00 pieces per plant, 2.63-4.03 pieces per pod, 115.6-131.7 g and 1659-1808 kg ha^{-1}, respectively. In terms of all examined properties in this research, 1000 kg ha^{-1} leonardite application produced the best result. According to the results obtained from this research, 1000 kg ha^{-1} leonardite application was recommended for broad bean cultivation in the semi-arid Mediterranean climate conditions on highlands.

Key words: Broad bean, Leonardite, Low input, *Vicia faba* L., Yield.

INTRODUCTION

Broad bean (*Vicia faba* L.) is one of the oldest crop in the world. Globally, it is the third most consumed pulse. Currently 58 countries produce it on large scale (Singh *et al.,* 2013). This protein-rich legume is well adapted to most climatic areas of Europe and widely used for feed and food (Crepon *et al.,* 2010; Paolo *et al.,* 2015). Broad bean is becoming increasingly popular in European agriculture due to economic and environmental reasons. It can be highly productive, but sensitive to drought stress and its yields can vary considerably from season to season (Link *et al.,* 2007). In cool-temperate regions, broad bean is mainly grown as a spring crop despite the higher yield potential of the winter type, due to insufficient winter-hardiness of the present winter genotypes (Arbaoui *et al.,* 2008). It is a cool season multi-purpose pulse with potential to be grown at short growth seasons. It is grown in many regions in the world due to its high nutritional value, medicinal effect, and effective biological nitrogen fixation (Cao *et al.,* 2017). Diverse benefits get obtained in ecosystems integrating broad bean in cropping systems (Etemadi *et al.,* 2019).

Organic fertilizer or soil amendment usage is an important component for sustainable agriculture (Sun *et al.,* 2016). Leonardite is an oxidized form of lignite obtained from coal mines. It has soil amendment potential and positive effects on crop growth and yield (Akinremi *et al.,* 2000). Leonardite has high amount of readily available organic matter content (Singkham and Ditthakit, 2019). Humic substances extracted from leonardite are considered as bioactive compounds, effecting the plant physiology and crop yield (Lingaraju *et al.,* 2016; Barone *et al.,* 2019). Humic substances are abundant in the environment which play important roles in biogeochemical processes like microbial activity, soil aggregation, plant growth, retention and release of nutrients, environmental fate of pollutants and carbon storage. They are flexible, relatively small molecules forming supramolecular structures through weak interactions (Petrov *et al.,* 2017). Humic substances has important roles in the biotic-abiotic interactions of the plant root and soil help plant to adapt to environments. However their mode of action on plants is largely unknown (Kulikova *et al.,* 2016). Leonardite have gained much attention as it can improve soil quality and immobilize herbicides in the subsurface, too (Sakulthaew *et al.,* 2021).

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The objective of this study was to assess the effects of different doses of leonardite on growth and yield traits of broad bean.

MATERIALS AND METHODS

Experimental site

This study was carried out in the growing season of 2017 and 2019 in order to determine the effects of different doses of leonardite on the yield and some yield characteristics of broad bean in Siirt province (semi-arid Mediterranean climate conditions on highlands of South Eastern Anatolia region of Turkey) conditions. Field trials were conducted in experimental fields of Siirt University. The study area soil was clayey-loam, poor in organic matter (0.9%), calcareous (1.6%), slightly alkaline (pH 7.6), rich in potassium (669 kg ha^{-1}) and poor in phosphorus (31.2 kg ha^{-1}).

Climate of the experimental site

The trials were carried out in the experimental fields of Siirt University. The average temperature values during the vegetation period in 2017 and 2019 were close to the long term averages. Total precipitation amount and average relative humidity values were above the long-term averages for both years of the study (Table 1).

Plant materials

Broad bean variety "Salkim" was used in the experiments. Salkim is a registered variety owned by the Aegean Agricultural Research Institute (Turkey). Its erect plant has average 37-70 cm plant height, 6.0-13.6 cm first pod height, 131-153 g 100 seed weight, 3.5-4.5 t/ha grain yield and bred for dry consumption (AARI, 2020).

Experimental design, treatments and cultural practices

The study was carried out in a randomized complete block design with three replications. In the autumn, the trial field was machine plowed, then in the spring, just before the planting, the cultivator and harrow was applied. Before planting, 0, 200, 400, 600, 800 and 1000 kg ha^{-1} doses of leonardite were spreaded on the plots and mixed in soil with rake. The leonardite used in the study was containing 35% organic matter, 40% total humic + fulvic acid, with pH 3-5 and granular form. Sawing lines were opened manually by a marker. Previous crop was wheat in crop rotation. Hand sowings of broad beans was conducted in the first week of March on four rows at each parcel to five m long rows, with 50 cm inter-row and 10 cm intra-row spacing at 4-5 cm sawing depth similar to Karadavut *et al.* (2011). The 2018 trial was canceled due to plant emergence problems and re-established in 2019. No irrigation was applied and rainfed cultivation method was followed. Weeds were managed manually. Fungicide spray was applied for the anthracnose disease for three times in 2017 and once in 2019.

Data collection

For observation and harvesting, border rows from each edges and 0.5 m from both ends of the plots were cut out. Observations were made on 10 plants selected from the remaining plants in parcels. Parcel harvest was conducted for yield determinations. The plants were harvested in the first week of July when the pods were dried and the grains got hardened. Harvesting and threshing processes were done manually. Plant height, first pod height, number of pods per plant, number of seeds per pod, 100-grain weight and grain yield were investigated.

Data analysis

The data were subjected to variance analysis and differences between the applications were determined by the $LSD_{(0.05)}$ test via JMP (version 5.0.1) software program.

RESULTS AND DISCUSSION

Average values related to the effects of different leonardite doses on yield and some yield characteristics of broad bean plants and LSD groups are given in Table 2. The effect of leonardite doses on plant height was found to be statistically significant for both years of the study. A lineer significant increase were observed for plant heights by increasing application doses of leonardite for both years. Highest plant heights were 60.0 cm and 61.3 cm for first and second years, respectively, and were obtained by 1000 kg ha^{-1} leonardite application (Table 2). The results obtained in this study were similar to the results of Azcona *et al.* (2011), Özel (2011)

Table 1: Meteorological data of experimental area*.

Months	Monthly average temperature (°C)			Monthly total precipitation (mm)			Monthly average relative humidity (%)		
	2017	2018	Long year average	2017	2018	Long year average	2017	2018	Long year average
March	9.6	8.3	10.1	119.2	182.0	92.3	63.9	63.5	59.2
April	14.0	11.9	15.3	132.8	175.6	91.7	59.5	66.8	53.8
May	19.5	21.9	20.0	74.6	64.4	69.5	51.7	41.8	49.6
June	26.9	29.1	27.0	0.0	1.2	10.8	29.5	26.5	28.7
July	32.3	30.2	30.6	0.0	0.0	2.7	19.0	23.0	23.3
Total/ Average	20.5	20.3	20.6	326.6	423.2	267.0	44.7	44.3	42.9

* Turkish State Meteorological Service, Siirt Province Official Records.

and İmamoğlu (2019), who reported increases as a result of leonardite applications.

The effect of leonardite doses on first pod height was found to be statistically significant for both years of the study. A lineer significant increase were observed for plant heights by increasing application doses of leonardite for both years. Highest first pod height values were 12.7 cm and 13.2 cm for first and second years, respectively and were obtained by 1000 kg ha^{-1} leonardite application (Table 2). Similarly, Öktem *et al.* (2017) reported that humic acid application increased the first pod height in their study.

The effect of leonardite doses on pod number per plant was found to be statistically significant for both years of the study. A lineer significant increase were observed for pod number per plant by increasing application doses of leonardite for both years. Highest pod number per plants were 7.4 pieces and 8.4 pieces for first and second years, respectively and were obtained by 1000 kg ha^{-1} leonardite application (Table 2). Similarly, Öktem *et al.* (2017) reported that humic acid application increased the pod number per plant.

The effect of leonardite doses on the number of grains per pod was found to be statistically significant for both years of the study (Table 3). The anthracnose disease was occured due to heavy rainfall in the first year which affected the development of plants and reduced the grain number per pod values compared to second year of the study. The effect of leonardite doses on grain number per pod was found to be statistically significant for both years of the study. A lineer significant increase were observed for grain number per pod by increasing application doses of leonardite for both years. Highest grain number per pod were 3.77 pieces and 4.03 pieces for first and second years, respectively, and were obtained by 1000 kg ha^{-1} leonardite application (Table 3). Batanay (2016) reported that humic acid increased the number of grains in the plant, similar to this study.

The anthracnose disease occured due to heavy rainfall in the first year adversely affected the development of plants and reduced the 100 grain weight values compared to second year of the study. The effect of leonardite doses on 100 grain weight was found to be statistically significant for both years of the study. A lineer significant increase were observed for 100 grain weight by increasing application doses of leonardite for both years. Highest 100 grain weight values were 129.6 g and 131.7 g for first and second years, respectively, and were obtained by 1000 kg ha^{-1} leonardite application (Table 3). Gürsoy (2016) and Mostofa and Akın (2017) found that leonardite increased the 100-grain weight.

Table 2: Averages and groups for plant height, first pod height and average number of pods per plant for different leonardite doses in 2017 and 2019.

	Plant height (cm)		First pod height (cm)		Pod number per plant (piece plant^{-1})	
Leonardite doses (kg ha^{-1})	2017	2019	2017	2019	2017	2019
Control	45.7 e	47.7 e	10.1 c	11.0 d	5.03 f	5.23 e
200	46.5 e	48.6 e	10.5 c	11.2 d	5.76 e	6.13 d
400	48.7 d	53.4 d	10.5 c	11.9 c	6.13 d	6.77 c
600	50.5 c	57.9 c	12.0 b	12.4 bc	6.53 c	7.07 c
800	54.6 b	58.9 b	12.3 ab	12.9 ab	7.03 b	7.57 b
1000	60.0 a	61.3 a	12.7 a	13.2 a	7.43 a	8.04 a
Mean	51.0	54.6	11.4	12.1	6.30	6.80
$LSD_{(0.05)}$	3.004	2.023	1.400	1.472	0.576	1.061

Different letters in the rows indicate significant differences according to LSD test (P≤0.05).

Table 3: The effects of the applications on the number of seeds per pod, 100-grain weight and grain yield of the pod plant.

	Grain number per pod (piece pod^{-1})		100 Grain weight (g)		Grain yield (kg ha^{-1})	
Leonardite doses (kg ha^{-1})	2017	2019	2017	2019	2017	2019
Control	2.63 e	2.93 c	115.6 e	121.2 e	1659 e	1708 f
200	2.93 d	3.03 c	117.0 d	121.5 e	1685 d	1718 e
400	3.13 c	3.43 b	117.7 d	123.1 d	1709 c	1740 d
600	3.17 c	3.57 b	122.6 c	126.0 c	1719 bc	1757 c
800	3.33 b	3.83 a	124.6 b	126.8 b	1726 b	1772 b
1000	3.77 a	4.03 a	129.6 a	131.7 a	1769 a	1808 a
Mean	3.16	3.47	121.2	125.1	1711	1751
$LSD_{(0.05)}$	0.309	0.516	2.059	1.494	28.06	18.19

Different letters in the rows indicate significant differences according to LSD test (P≤0.05).

Ergönül (2011) found that leonardite application reduced the 100-grain weight, Öktem *et al.* (2017) reported that the application of humic acid was not affective for the 100 grain weights. These differences in the studies may be sourced from the cultivars, applied leonardite types and doses, application methods and the differences in the climate and soil conditions.

The anthracnose disease occured due to heavy rainfall in the first year negatively affected the development of plants and reduced the grain yield values compared to second year of the study. The effect of leonardite doses on grain yield values were found to be statistically significant for both years of the study. A lineer significant increase were observed for grain yield by increasing application doses of leonardite for both years. Highest grain yield values were 1769 kg/ha and 1808 kg/ha for first and second years, respectively and were obtained by 1 t/ha leonardite application (Table 3). Ergönül (2011), Öktem *et al.* (2017) and Öztürk (2010) reported increased grain yields with leonardite applications similar to this study.

CONCLUSION

As a result of the study, it was determined that the leonardite applications were found beneficial to increase grain yields and to improve yield components in broad beans under low input, semi-arid Mediterranean conditions on highlands of South Eastern Anatolia region of Turkey. In both years of the study, as the dose of leonardite increased from 0, 200, 400, 600, 800 and 1000 kg ha^{-1}, plant height, first pod height, number of pods per plant, number of grains per pod, 100 grain weight and grain yield were also increased. Highest grain yield values were 1769 kg/ha and 1808 kg/ha for the first and second years, respectively and were obtained by 1000 kg ha^{-1} leonardite application.

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