

EFFECT OF DIFFERENT LEONARDITE DOSES AND CROSS-SOWING METHODS ON THE GROWTH AND YIELD OF RED LENTIL

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ABSTRACT. This study was carried out to determine the effect of different cross-sowing methods and different doses of leonardite on the growth of red lentils under rain-fed conditions. Treatments consisted of different cross-sowing methods (control, 45° cross-sowing and 90° cross-sowing) and different leonardite doses (0, 500, 1000, 1500, 2000 and 2500 kg ha⁻¹). The trial was carried out in Diyarbakır province in Türkiye. The same rate of leonardite was applied to the same plots for two consecutive years to observe the two-year effect of leonardite in the experiment, which was established with four replications according to the factorial experimental design in the 2018-2019 and 2019-2020 production seasons. A positive effect of leonardite application was observed on the number of nodules and fresh root weight in the first production season. The highest nodule number (11.84) was obtained with 2500 kg ha⁻¹ and

the highest fresh root weight (0.24, 0.25 and 0.24 g) was obtained at 500, 1000 and 1500 kg ha⁻¹ doses, respectively. The highest plant height, number of main branches, and number of pod parameters were obtained at a dose of 1500 kg ha⁻¹ in the second production season (36.63 cm, 3.95 and 17.43, respectively). The highest grain yield (889.5 kg ha⁻¹), dry root weight (0.125 g) and number of nodules (50.01) were obtained at a dose of 1000 kg ha⁻¹ in the second production season. It was determined that different sowing methods did not affect grain yield in either production season.

Keywords: cross-sowing; leonardite; red lentils.

INTRODUCTION

Canada and India have the largest lentil production area in the world, respectively. Türkiye ranks 4th in red



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lentil production area (Demirel and Sessiz, 2023). In Türkiye, 96% of red lentil production occurs in the southeastern Anatolia region. The three provinces where red lentils are produced the most in the southeastern Anatolia region are Şanlıurfa, Diyarbakır and Mardin (TUIK, 2023).

Organic soil conditioners can be applied to improve some soil properties and to improve the physical properties of the soil (Alagöz *et al.*, 2006; Ferrini *et al.*, 2005; Kolay *et al.*, 2016; Saraç, 2018; Ulukan, 2008). Therefore, they generally have a positive effect on yield. Leonardite is an organic soil conditioner with significant resources in Türkiye.

In Türkiye, where there are very important lignite sources, considering the leonardite formation conditions, every lignite source is a potential leonardite source (Engin *et al.*, 2012).

The availability of significant resources allows this material to be obtained more cheaply by farmers. It is important to investigate the availability of this material, which is affordable and easily available in Türkiye, in agriculture.

There are very few studies on leonardite applications in lentil cultivation. Dogan *et al.* (2014) applied different doses of leonardite to lentil (0, 300 and 600 kg ha⁻¹) and stated that the highest seed yield was obtained from the application of 600 kg ha⁻¹. However, no study has been found on the effect of higher doses on lentils.

Agricultural production consists of many factors. For successful and efficient agricultural production, there must be soil with positive properties, as well as a fertile variety and appropriate agronomic practices. The sowing

method is an important agronomic application that directly affects yield. Cross-sowing is a sowing method that is mostly applied to cereals, and it aims to narrow the habitat of weeds by expanding the living area of cultivated plants. Chaudhary *et al.* (2013), Chhokar *et al.* (2012), Jat *et al.* (2003), Hussain *et al.* (2018), Kaydan and Geçit (2005), Kaydan *et al.* (2011), Singh *et al.* (2020), and Tomar (2004) evaluated the cross-sowing method in cereals and determined its positive effects on yield. However, there are very few studies on the effect of cross-sowing methods on the yield of red lentils.

In a study conducted by Toğay and Anlarsal (2008) in eastern Türkiye, different sowing methods were examined in red lentils.

They obtained the highest grain yield from the row seeding method in the first year of the study and from the row seeding method and 90° cross-sowing in the second year. In addition to very large irrigable areas in the southeast of Türkiye, there are also large agricultural lands where production is based on rain-fed conditions. The cereal–legume rotation system is mostly applied in these areas. The soil texture of these areas is mostly clay and clay loam, and the organic matter content is low. Red lentils are the most cultivated legumes in these areas. Red lentils are very important for human nutrition due to their protein content.

According to data from the Turkish Statistical Institute, the production of red lentils in Türkiye increased from 228,000 tonnes in 2021 to 400,000 tonnes in 2022.

A very important portion of red lentil growth in Türkiye occurs in

southeast Türkiye. The rate of use of chemical fertilisers by farmers in the production of red lentils in these areas is also very low.

This study was carried out to determine the effect of different doses of leonardite application to the soil and different cross-sowing methods on plant growth in red lentil cultivation in Diyarbakır province located in southeast Türkiye.

As a result of this study, the applicability of cross-sowing and the effect of leonardite applications on plant growth were determined in red lentils.

MATERIALS AND METHODS

Experimental location

This study was carried out in the 2018-2019 and 2019-2020 red lentil production seasons in Diyarbakır province under rainfed conditions.

Materials

The red lentil variety Fırat-87 was used as plant material. This variety was used because it is widely cultivated in Diyarbakır and is disease resistant. Leonardite obtained from the leonardite deposits of the Elbistan district was used in this experiment.

Namlı *et al.* (2017) emphasised the importance of evaluating humic acid, organomineral and organic soil conditioner materials in the Afşin-Elbistan Lignite Pit area as an organic soil conditioner, organomineral fertiliser, K-humate, and humic acid.

Caniren (2015) reported that quality products containing high humic substances can be produced from leonardite obtained from the Afşin-Elbistan region in Kahramanmaraş

province. Leonardite obtained from Afşin-Elbistan leonardite deposits and commercially available was used in this study. The properties of the leonardite used in the experiment are shown in *Table 1*.

Table 1 – Some properties of leonardite used in the experiment

Properties	Content
Organic matter	75.05%
Humic+Fulvic acid	95.46%
EC	1.94 mmhos cm ⁻¹
pH	5.76
Moisture	35%
CaCO ₃	2.27%
Total nitrogen	1.3%
Total phosphorus	0.45%
Total potassium	0.07%
Total sulphur	6.12%
Total sodium	0.90%
Total calcium	14 569 mg kg ⁻¹
Total magnesium	2 825 mg kg ⁻¹
Total boron	37 mg kg ⁻¹
Total iron	9273 mg kg ⁻¹
Total copper	4.76 mg kg ⁻¹
Total manganese	26.67 mg kg ⁻¹
Total chrome	44.65 mg kg ⁻¹
Total molybdenum	10.72 mg kg ⁻¹

According to the classification made by Şengüler (2015), the leonardite used in the study is of high quality, with a humic acid and organic matter content and medium quality in terms of pH.

Soil and climatic data

The soil properties of the field where the experiment was carried out are shown in *Table 2*.

The climate characteristics of the area where the trial was conducted are shown in *Table 3*.

As shown in *Table 3*, in the 2018-2019 red lentil production season, there was more rainfall than the long year

average in October, November and December.

Table 2 – Some soil characteristics of the trial area

Properties	Content
Saturation	72.5%
Texture	Clay
Sand	25.84%
Clay	56.50%
Silt	17.66%
Total salt	0.023%
pH	7.70
CaCO ₃	7.31%
Plant available P ₂ O ₅	14.9 kg ha ⁻¹
Plant available K ₂ O	943.8 kg ha ⁻¹
Organic matter	0.96%
Field capacity	46.92%
Wilting point	19.91%
Bulk density	1.52 g cm ⁻³
Cation exchange capacity	23 me 100 g ⁻¹

Experimental design and treatment details

In this experiment, 6 leonardite doses (0, 500, 1000, 1500, 2000 and 2500 kg ha⁻¹) and 3 sowing methods (control, 45° cross sowing and 90° cross sowing) were applied. All seeds were sown with 20 cm row spacing in the control application.

In the cross-sowing method with an angle of 45°, half of the seed to be sown was planted with a 20 cm row spacing, and the remaining half was sown on the first sown rows at an angle of 45°.

In the cross-sowing method with an angle of 90°, half of the seed to be planted was planted with a 20 cm row spacing, and the remaining half was planted horizontally on the parcel with an angle of 90° on the first sown rows. There were 300 m⁻² plants per unit area in all three sowing methods.

In this study, which was carried out in 4 replications according to the

factorial experimental design, the same applications were applied on the same plots for two years.

Cultural practices

The same applications were applied to the same parcels in both production seasons. In both production seasons, before sowing, the trial area was cultivated with a plough + cultivator + cultivator, and parcels were prepared. Leonardite was applied to the parcels at determined doses and mixed into the soil at a depth of 10 cm.

The trial was then sown with a planting machine. In the spring, the spaces between the parcels were hoed with a power tiller. In addition, the weeds in the parcel were removed by hand. Root samples were collected and examined during the 50% flowering period. The trial was harvested in June after other vegetative observations.

Data collection

The plant height, number of main branches, and number of pods were determined in 10 randomly selected plants from each plot. Afterward, harvesting was performed with a combine harvester, and plot yield was determined. Grain yield per unit area was calculated by converting this yield value to hectares. The weight of 100 red lentil seeds obtained from each plot was determined with 4 replications, and this number was multiplied by 10 to determine the weight of 1000 seeds. On the date when 50% of the plants in each plot flowered, 10 plants were randomly sampled without damaging the roots and washed with water in a bucket.

The average was calculated after counting the number of nodules on the roots (Erdemci, 2012). To determine the

fresh root weight after nodule counting, the roots were weighed, and the average of 10 plants was calculated. The dry root weight was determined by weighing these roots after drying them in the oven at 70°C for 24 hours (Kahrıman *et al.*, 2019).

Statistical analysis

The obtained data were evaluated by two-way analysis of variance (ANOVA), and the least significant difference (LSD) test was applied to the important data. Statistical grouping occurred at 5% and 1% significance levels. Statistical analyses were performed using JMP 7.0 statistical software.

RESULTS

The data obtained in this study were evaluated separately according to both the years and the two-year average data of the applications in a combined analysis. The data for the 2018-2019 production season in which the study was carried out are shown in *Table 4*.

As shown in *Table 4*, leonardite did not affect the surface parts of the plants after application to red lentil in the first production season. Plant height, number of main branches, number of pods, grain yield, and 1000 grain weight were not affected by leonardite application.

The highest number of nodules in the plant occurred at a dose of 2500 kg ha⁻¹ in the first application year. The fresh root weight of the plant increased with leonardite application, but decreased again at the highest leonardite dose.

In the first year of the study, the sowing method was effective only on fresh and dry root weights. The highest

fresh root weight was obtained from 90° cross-sowing, and the highest dry root weight was obtained from the control and 90° cross-sowing applications.

In the second production season of the study, the same applications were applied to all parcels, and the effect of the same applications for two consecutive years was determined. The data obtained in the second production season are shown in *Table 5*. Leonardite application for two consecutive years had a significant effect on plant growth, as shown in *Table 5*. The plant height, number of main branches and number of pods were highest in the 1500 kg ha⁻¹ application, while grain yield, number of nodules and dry root weight were higher in the 1000 kg ha⁻¹ application. As a result of applying different leonardite doses to the soil during red lentil cultivation, there was no difference in the aboveground parts of the plant (plant height, number of main branches per plant, number of pods per plant, grain yield and 1000 seed weight) in the first production season. However, the root development was affected by leonardite application. The fresh root weight of the plant was higher in 500, 1000 and 1500 kg ha⁻¹ leonardite applications. Additionally, nodule formation on plant roots was higher in the 2500 kg ha⁻¹ leonardite application than in other applications.

In the second production season, when the same dose of leonardite was applied to the same plot, both the aboveground part and the root development of the plant were affected by leonardite application.

Table 3 – Climate characteristics of the trial area

Production Season	Data Examined	Month					
		October	November	December	January	February	March
Long Year Average	Average temperature (°C)	17.5	9.7	4.0	1.7	3.7	8.3
	Monthly Total Precipitation (mm)	33.0	55.2	72.3	70.7	67.6	66.7
2018-2019	Average temperature (°C)	18.7	10.2	6.2	3.9	5.3	8.2
	Monthly Total Precipitation (mm)	76.6	88.2	190.8	67.6	77.4	135.2
2019-2020	Average temperature (°C)	19.1	9.7	6.8	3.6	3.7	10.6
	Monthly Total Precipitation (mm)	52.0	9.0	185.4	89.4	58.6	164.8
							110.0
							63.2
							0.6

Table 4 – Averages and multiple comparison results of the parameters examined in the 2018-2019 production season

Leonardite doses (kg ha ⁻¹)	Traits						
	Plant height (cm)	Number of main branches per plant	Grain yield (kg ha ⁻¹)	1000 seed weight (g)	Nodule number per plant	Fresh root weight of the plant (g)	Dry root weight of the plant (g)
0	33.40	3.33	679.8	32.44	8.01 c	0.18 b	0.082
500	32.88	3.48	658.7	31.58	8.39 bc	0.24 a	0.093
1000	33.85	3.40	644.7	31.66	9.78 b	0.25 a	0.091
1500	33.41	3.41	702.1	31.94	9.80 b	0.24 a	0.093
2000	32.27	3.46	683.0	32.16	9.91 b	0.21 ab	0.080
2500	32.86	3.11	717.3	32.13	11.84 a	0.18 b	0.090
Mean	33.11	3.36	680.93	31.98	9.62	0.21	0.088
Sowing methods							
Control	33.64	3.25	664.4	31.98	9.86	0.19 b	0.096 a
45° C.S.	32.78	3.44	654.3	32.27	9.40	0.19 b	0.074 b
90° C.S.	32.92	3.40	725.6	31.70	9.60	0.28 a	0.095 a
Mean	33.11	3.36	681.43	31.98	9.62	0.22	0.088
CV (%)	5.17	18.46	16.90	3.26	21.94	31.82	31.82
LSD (0.05)	S.M.: n.s. Leo: n.s.	S.M.: n.s. Leo: n.s.	S.M.: n.s. Leo: n.s.	S.M.: n.s. Leo: n.s.	S.M.: n.s. Leo: 1.72	S.M.: 0.04 Leo: 0.06	S.M.: 0.2 Leo: n.s.
Significance levels	S.M.: - Leo: -	S.M.: - Leo: -	S.M.: - Leo: -	S.M.: - Leo: -	S.M.: - Leo: **	S.M.: ** Leo: *	S.M.: ** Leo: -

-: There is no significance levels, *Statistical significance: p<0.05, **Statistical significance: p<0.01, n.s.: denotes not statistically significant at p<0.05, S.M.: Sowing methods, Leo: Leonardite

Table 5 – Averages and multiple comparison results of the parameters examined in the 2019–2020 production season

Leonardite doses (kg ha ⁻¹)	Traits							
	Plant height (cm)	Number of main branches per plant	Number of pods per plant	Grain yield (kg ha ⁻¹)	1000 seed weight (g)	Nodule number per plant	Fresh root weight of the plant (g)	Dry root weight of the plant (g)
0	35.34 bc	2.79 d	13.27 cd	730.3 b	33.91	36.47 b	0.53	0.091 d
500	34.55 c	3.10 c	15.50 b	817.5 ab	35.02	39.95 ab	0.63	0.123 ab
1000	35.82 a-c	3.25 bc	11.72 d	889.5 a	34.45	50.01 a	0.63	0.125 a
1500	36.63 a	3.95 a	17.43 a	755.9 b	31.81	35.26 b	0.57	0.096 cd
2000	36.33 ab	3.34 bc	16.07 ab	755.3 b	33.93	37.54 b	0.63	0.107 bc
2500	34.15 c	3.40 b	14.65 bc	713.9 b	33.05	35.65 b	0.55	0.103 cd
Mean	35.47	3.30	14.77	777.06	33.69	39.14	0.59	0.107
Sowing methods								
Control	34.83 b	3.23 b	14.87 b	771.5	32.50 b	37.77	0.55	0.100 b
45° C.S.	35.12 b	3.64 a	16.04 a	784.8	35.21 a	38.50	0.62	0.108 ab
90° C.S.	36.46 a	3.04 c	13.58 c	777.3	33.43 ab	40.90	0.59	0.112 a
Mean	35.47	3.30	14.83	777.86	33.71	39.05	0.58	0.106
CV (%)	4.32	8.79	12.55	19.68	10.39	29.75	23.73	10.00
LSD (0.05)	S.M.: 0.92 Leo: 1.34	S.M.: 0.16 Leo: 0.24	S.M.: 1.08 Leo: 1.50	S.M.: n.s. Leo: 128.6	S.M.: 2.34 Leo: n.s.	S.M.: n.s. Leo: 10.09	S.M.: n.s. Leo: n.s.	S.M.: 0.010 Leo: 0.015
Significance levels	S.M.: ** Leo: **	S.M.: ** Leo: **	S.M.: ** Leo: **	S.M.: - Leo: *	S.M.: * Leo: -	S.M.: - Leo: *	S.M.: - Leo: -	S.M.: * Leo: **

-, There is no significance levels, *Statistical significance: p<0.05, **Statistical significance: p<0.01, n.s.: denotes not statistically significant at p<0.05, S.M.: Sowing method, Leo: Leonardite

The highest plant height, number of branches per plant and number of pods per plant were obtained from the 1500 kg ha⁻¹ leonardite application, while the highest grain yield, number of nodules per plant and dry root weight of the plant were obtained from the 1000 kg ha⁻¹ leonardite application.

The effect of leonardite application on the root development of the plant was observed in both production seasons, while its effect on the aboveground parts of the plant was observed in the second production season. In terms of the examined parameters, notable statistical differences occurred in the first and second production seasons.

As shown in *Table 6*, considering the average data of the two production seasons, the grain yield was highest with the application of 90° cross-sowing and a 1500 kg ha⁻¹ leonardite dose.

DISCUSSION

As a result of the combined analysis considering the two-year average data, *Table 7* shows that the highest plant height was obtained from 1000 and 1500 kg ha⁻¹ applications of leonardite.

The highest number of main branches and pods was found with 1500 kg ha⁻¹, and the highest dry root weight was found with 500 and 1000 kg ha⁻¹ applications. The fresh root weight increased with leonardite application but decreased with a 2500 kg ha⁻¹ application.

As a result of the combined analysis, there was no statistical difference in the grain yield parameter, but the highest yield was observed in the 1000 kg ha⁻¹ application.

Table 6 – Effects of leonardite dose and cross-sowing method and their interaction on red lentil yield (mean of two years)

Mean of two years				
Leonardite Doses (kg ha ⁻¹)	Sowing methods			
	Control	45° C.S.	90° C.S.	Mean
0	697.6 b–e	701.7 b–e	718.9 a–d	704.0
500	743.1 a–d	739.0 a–d	737.6 a–d	737.0
1000	794.3 ab	719.4 a–d	775.5 a–c	752.3
1500	589.5 e	699.8 b–e	841.2 a	710.2
2000	776.6 a–d	651.8 c–e	642.2 de	687.1
2500	681.9 b–e	791.3 ab	723.5 a–d	735.7
Mean	704.7	715.3	742.4	
Year Average				
2018-2019			2019-2020	
675.6 b			769.7 a	
CV (%)		16.67		
LSD (0.05)		Yil: 43.3 S.M.: n.s. Leo.n.s. S.M.+Leo.: 131.4		
Significance levels		Yil: ** S.M.: - Leo.- S.M.+Leo.: **		

-: There is no significance levels, *Statistical significance: $p < 0.05$, **Statistical significance: $p < 0.01$, n.s.: denotes not statistically significant at $p < 0.05$, S.M.: Sowing methods, Leo: Leonardite

Table 7 – Data obtained as a result of a two-year combined analysis

Leonardite doses (kg ha ⁻¹)	Traits					
	Plant height (cm)	Number of main branches per plant	Number of pods per plant	Grain yield (kg ha ⁻¹)	1000 seed weight (g)	Fresh root weight of the plant (g)
0	34.28 b	3.06 c	12.02 d	704.0	33.92	0.086 c
500	33.72 b	3.29 bc	14.18 ab	737.0	33.30	0.110 a
1000	35.00 a	3.32 b	12.39 cd	752.3	33.06	0.107 ab
1500	34.96 a	3.77 a	14.88 a	710.2	32.08	0.094 bc
2000	34.30 ab	3.40 b	14.13 a-c	687.1	33.40	0.093 c
2500	33.87 b	3.26 bc	13.01 b-d	735.7	33.34	0.097 a-c
Sowing methods						
Control	34.56 a	3.28 b	13.86 a	704.7	33.00 b	0.37
45° C.S.	33.95 b	3.54 a	14.07 a	715.3	33.90 a	0.39
90° C.S.	34.57 a	3.22 b	12.34 b	742.4	32.62 b	0.42
Year Average						
2018-2019	33.11 b	3.39	11.87 b	675.6 b	31.94 b	0.20 b
2019-2020	35.71 a	3.30	14.93 a	769.7 a	34.54 a	0.59 a
CV (%)	4.62	13.44	20.26	16.67	6.30	28.21
L.S.D (0.05)	S.M.: 0.65	S.M.: 0.18	S.M.: 1.08	S.M.: n.s.	S.M.: 0.87	S.M.: n.s.
	Leo: 0.95*	Leo: 0.25	Leo: 1.56	Leo: n.s.	Leo: n.s.	Leo: 0.063
	Yil: 0.53**	Yil: n.s.	Yil: 0.91	Yil: 43.3	Yil: 0.71	Yil: 0.035
Significance levels	S.M.: *	S.M.: **	S.M.: **	S.M.: -	S.M.: **	S.M.: *
	Leo: *	Leo: **	Leo: **	Leo: -	Leo: -	Leo: *
	Yil: **	Yil: -	Yil: **	Yil: **	Yil: **	Yil: **

-. There is no significance levels, *Statistical significance: p<0.05, **Statistical significance: p<0.01, n.s.: denotes not statistically significant at p<0.05, S.M.:Sowing methods, Leo: Leonardite

Although the number of main branches, number of pods, and 1000 seed weight were higher when using the 45° cross-sowing method, there was no difference in grain yield between the sowing methods.

Although many studies have been carried out on different plants, there are very few studies on cross-sowing methods in lentils. Kolay and Öztürkmen (2021) determined that the 90° cross-sowing method is applicable in terms of weed control.

Cross-sowing methods are mostly applied in cereals and aim to decrease the number and weight of weeds by increasing yield. In the last 5 years, Hussain *et al.* (2018) and Singh *et al.* (2020) researched cross-sowing in cereals and determined their positive effects on yield. Chornobay *et al.* (2018) reported that cross-sowing in soybean increased nodule formation but did not increase yield.

In another region of Türkiye, Toğay and Anlarsal (2008), who examined different sowing methods for red lentils, obtained the highest grain yield from row sowing in the first year and from 90° cross-sowing in the second year. The results obtained from this study are not similar to Toğay and Anlarsal (2008).

Although studies have been carried out on different plants using leonardite applications and cross-sowing methods, studies on red lentil plants are very limited. Çay (2018) showed that leonardite increased strawberry yield. İmamoğlu (2019) suggested leonardite application in beans. Jomhataikool *et al.* (2019) determined that humic acid and

leonardite increased leaf and root growth in rice.

According to Kiyas (2020), the use of leonardite in bean plants in a salty environment increased both its growth and ion uptake. Wang *et al.* (2020) determined that the evacuated salt increased and the EC value decreased in parallel with the increase in the leonardite dose. Kaya *et al.* (2020) reported that sulphur-enriched leonardite and humic acid materials could be used to preserve the yield of maize crops. Uçar *et al.* (2020) suggested using leonardite at a dose of 1000 kg ha⁻¹ in chickpeas. Uçar *et al.* (2021) recommended the application of 1000 kg ha⁻¹ leonardite in broad bean cultivation in semi-arid Mediterranean climate conditions on highlands.

Nuon *et al.* (2022) stated that the application of leonardite together with chemical fertilisers could increase growth and yield in cowpea. Akay and Omar (2022) reported that Cordes roses to which leonardite was applied were healthier than those to which it was not applied. Dogan *et al.* (2014) applied doses of 0, 300 and 600 kg ha⁻¹ leonardite to lentil plants.

The highest plant height, first pod height, number of branches per plant, pods per plant, seeds per plant, seed yield, biological yield, harvest index, and 1000 seed weight were obtained from 600 kg ha⁻¹ application in both years.

However, in this study, the effect of higher leonardite applications on the growth of lentils was not observed. In this study, a higher yield was obtained from a 1000 kg ha⁻¹ leonardite application, and the gap in the literature

was completed. In addition, because of the two-year application in this study, the negative effects of 2000 and 2500 kg ha⁻¹ high doses on the yield, yield parameters and root development of the plant were determined.

CONCLUSIONS

This study was carried out to determine the effect of different doses of leonardite applications and different cross-sowing methods on red lentils grown in rainfed conditions in southeast Türkiye. In this study, the same applications were applied to parcels for two consecutive years.

Leonardite application was only effective on roots in the first production season and had no effect on the grain yield in red lentils in the first production season. However, the highest grain yield was obtained from the 1000 kg ha⁻¹ application in the second production season. Leonardite was effective on grain yield in red lentils because of its application in two consecutive production seasons.

It was observed that grain yield increased at doses of 500 and 1000 kg ha⁻¹. Different cross-sowing methods were effective only on the dry root weight of the plant in the first production season. The dry root weight of the plant was higher using row sowing (control application) and 90° cross-sowing methods.

In the second production season, plant height and dry root weight of the plant were higher using the 90° cross-sowing method, while in the 45° cross-sowing method, the number of main

branches per plant, number of pods per plant and 100 seed weight were higher.

However, no difference was observed between planting methods in terms of grain yield in either production season. As a result of this study, considering the average data of both production seasons, no sowing method was recommended since there was no statistical difference in grain yield between the sowing methods. The application of 1000 kg ha⁻¹ leonardite may be recommended for red lentil cultivation.

However, leonardite did not increase grain yield in the first production season but affected root development. In the second production season, the highest grain yield was obtained from the 1000 kg ha⁻¹ application.

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