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Research Paper

Effect of Vermicompost Application at Different Sowing Dates on some Phenological, Agronomic and Yield Traits in Lentil[#]

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Abstract: Grain legumes are the most produced crops in all but cereals for all over the World and lentil is one of the most substantial of them. Vermicompost can play an effective role in crop growth and also in reducing the harmful effects of various chemical fertilizers. Besides, vermicompost application has various positive effects on the chemical and physiological traits of soil in a short and long time. Also, appropriate sowing time and scheduled application of nutrients are required by the plant for high quality product and grain yield. This study was carried out to determine the effects of vermicompost on plant growth, seed yield and yield components depending on different sowing times. According to results, seedling emergence time and flowering time varied between 11.0-25.3 days and 130.7-181.7 days, respectively. Plant height, number of pods per plant, number of seeds per pod and seed yield changed between 35.8-57.1 cm, 20.8-54.5 pod plant^{-1}, 1.13-1.51 pieces pod^{-1} and 922-2527 kg ha^{-1}, respectively. Therefore, the most suitable sowing date for winter lentil was determined as of December 1st in the Siirt. Therefore, 250 kg da^{-1} vermicompost applied in December 1st is recommended to gain the highest seed yield. Accordingly, vermicompost might be an effective alternative to reduce harmful effects of chemical fertilizer to environment. However, long-term researches are needed to understand whether vermicompost is a cost-effective material or not in lentil cultivation.

Keywords: *Delay sowing, Drought stress, Microbial activity, Short-term effect,*

Introduction

Legumes rank second after cereals in the world in terms of growth area and production amount. The most commonly produced grain legumes are dried bean, chickpea, cowpea, pea, lentil and broad bean, respectively. The total lentil harvested area in the world is 6.1 million hectares and total production is 7.6 million tones. Nearly 3.7 million tonnes of total production are growth by Canada (FAO, 2019). Lentil (*Lens culinaris* Medik.) is planted throughout the world to get seeds for human food and straw for animal feed**.** Wheat from cereals and lentil from legumes are always considered to be strategic commodities worldwide (Al-Antary & Thalji, 2017; Soysal *et al*., 2020).

Due to the lack of a selective plant in terms of soil demand, lentil enables to be cultivated in a wide area. However, light soils are more suitable for lentil cultivation. Also, low water demand and growing in poor soil make lentil an important part of crop rotation systems (Erskine *et al*., 2018).

The two main factors needed are selecting the most suitable variety and right fertilizer management to obtain maximum grain yield and quality in agricultural production. Otherwise, grain yield decreases and chemical composition weakens. However, excessive chemical fertilizer using has been threatening nature life and soil composition. So, the arising problems with the widespread use of synthetic fertilizer revealed the importance of organic fertilizers (Nobile *et al*., 2020).

In comparison with other organic fertilizers, vermicompost consists of high levels of nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium, as well as micronutrients such as iron, zinc, copper and manganese (Ceritoglu *et al*., 2019). Vermicompost, a valuable organic fertilizer, is rich material in terms of nutrition, antioxidants, vitamins, humic and phenolic substances and various hormones (Joseph, 2019). Vermicompost has positive effects when used appropriate doses and methods. Vermicompost is highly porous, allows high ventilation, good drainage and has a high water storage capacity. Vermicompost can play an effective role in plant growth and also in reducing harmful effects of various environmental stresses on plants due to its porous structure, high-water storage, having hormone-like substances and also high levels of macro and micronutrients. Study on the effects of

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[#]*This article was drived from M.Sc. tesis of Mustafa Ceritoglu* organic fertilizer such as vermicompost demonstrated that using this fertilizer can increase nitrogen in the soil by about 42%, phosphorus by about 29% and potassium by 57% (Sharma & Banik, 2014).

Due to environmental pollution, health problems and reactions caused by artificial growth enhancers, it should have used an eco-friendly fertilizer. For that, the aim of this study is to evaluate the effect of vermicompost on plant growth, grain yield and yield components in lentil depending on different sowing times.

Material and Methods

Study site and location

The study has been carried out at Siirt University during the winter season of 2018-2019. The area where the study was conducted is located on 41° 58' east longitude and 37° 56' north latitude, Southeastern Anatolia Region of Turkey. The altitude of the region is 880 m.

Soil analysis and climatic traits

The soil samples taken from 0-20 cm depth were analyzed in Siirt University Central Laboratory to determine the properties. The soil of the study area was composed of medium-deep soil which is low in organic matter and soluble phosphorus content, enough in potassium. Also, it was mild saline and limy. The texture was clay loam, pH was light alkaline near neutral (Fmanr, 1990). Traits of the soil were given in Table 1.

Table 1. Some chemical traits of soil taken from study area at the beginning of the study

Depth (cm)	Texture	pH (1:1)	EC (dS/m)	Lime $CaCO_3$ (%)	Organic matter (%)	Phosphorus (P_2O_5) (kg da^{-1})	Potassium (K_2O) (kg da^{-})
0-20	Clay-loam	7.62	6.73	9.5	0.6	1.57	163

The region has characteristics of terrestrial climate. Temperature values of vegetation period were nearly similar to the long years' average ranges. However, the rainfall and humidity during growth season were erratic and higher compared with the long years' average. Some climate data were given in Table 2.

Table 2. Some climate data of the region

Months	Precipitation (mm)		Av. temperature (°C)		Relative humidity (%)	
	2019	LYM	2019	LYM	2019	LYM
October	100.6	64.7	20.2	18.7	47.8	45.3
November	88.6	64.6	11.0	11.0	76.2	60.8
December	117.6	85.9	6.7	5.5	82.0	71.0
January	96.2	101.3	4.0	4.0	72.5	72.8
February	103.2	83.5	5.8	6.0	66.9	66.3
March	182.0	92.3	8.3	10.1	63.5	59.2
April	175.6	91.7	11.9	15.3	66.8	53.8
May	64.4	69.5	21.9	20.0	41.8	49.6
June	1.2	10.8	29.1	27.0	26.5	28.7
Total	990	673				
Mean			13.2	13.1	60.4	56.4

(*Av: Average, LYM: Long years mean)*

Variety of seeds used, cultivation of crop and field preparation

The cv. Fırat-87, the origin of ICARDA, was used in the study. Fırat-87 is a large-seed lentil variety registered in 2012 by Gaputaem (2019). It is the most commonly used cultivar in the region for many years and has a stability in terms of growth and yield performance. The vermicompost was supplied from a traditional company and traits of it were given in Table 3. The experimental layout was split-plot randomized complete block design with 3 replications and carried out in 2018-2019.

Table 3. Physico-chemical parameters of vermicompost used in the study

Organic matter (%)	35
Total nitrogen (%)	1.2
Organic nitrogen (%)	1.0
C/N	14
Maximum EC (dS/m)	5.0
Total humic ve fulvic acid (%)	20
Maximum moisture (%)	35
pH	6.8-8.5
Total phosphorus (P_2O_5) (%)	1-2
Total potassium (K_2O) (%)	1.5-2.5

Treatments of vermicompost and sowing dates

The field set up of the experiment was with 5 m^2 (5 x 5 x 0.2) plot size where 5 rows per plot and row spacings were set as 20 cm (Kraska *et al.*, 2020). The distances per plot and blocks were set as 1.5 m facilitating vermicompost application.

In the study, 5 doses of vermicompost (control, V1: 250 kg da^{-1}, V2: 500 kg da^{-1}, V3: 750 kg da^{-1} and V4: 1000 kg da^{-1}) and 5 different sowing dates (S1: 15 October, S2: 1 November, S3: 15 November, S4: 1 December and S5: 15 December) were used as a factor.

The 8 kg da^{-1} seed were sown in per plot (Tepe *et al.*, 2005). Also, 14 kg DAP da^{-1} was applied with sowing under the seed drill (Dona *et al.*, 2020). The study was carried out in dry conditions. Weed control was realized by mechanical methods in two times (2 weeks after the emerging and beginning of flowering) and herbicide applied once time, 45 days after sowing, for tenuifolious plants.

Sampling and data collection

The seedling emergence time (SET), flowering time (FT), plant height (PH), number of pods per plant (NP), number of seeds per pod (NS) and seed yield (SY) were researched in the study. The SET was determined when 90% of the plants in the per plot were seen on the soil surface. The FT was calculated from sowing to 50% of plants per plot achieved to flowering. The 10 plants were chosen from per plot to determine the PH and NP before harvest. The NS was determined with counting of seeds in 100 pods taken from per plant. Just complete and fit pods and seeds were counted. The plants in outer sows and 0.5 meters from their ends were eradicated and the rest of the plot was harvested and dried to calculate the SY for 1 ha/ area (Uçar, 2020).

Statistical analysis

Firstly, the Shapiro-Wilk test was applied to determine the normality of values (Korkmaz *et al.*, 2014). Statistical calculations were analyzed in the R (V.3.5.2) according to the split plots randomized complete block design and grouped according to TUKEY test. According to the results of multiple comparison tests, significant differences ($P<0.05$ and $P<0.01$) were determined between vermicompost applications and sowing dates for all traits (Mangiafico, 2016).

Results

According to the results, sowing dates and vermicompost doses showed statistically significant (0.01 or 0.05) effects on tested traits. In addition, the interaction between sowing date and vermicompost was statistically significant in all yield parameters (Table 4). Interaction between planting date and vermicompost was determined more significant on NP and SY (0.01) compared with NS (0.05). The greatest yield attributes were obtained when seeds were sown in 4_{th} sowing time and treated with 250 kg da^{-1} vermicompost (Table 10). On the other hand, the lowest seed yield was obtained with 750 kg da^{-1} vermicompost applied in 2_{nd} sowing time. The highest NP was obtained with 500 kg da^{-1} vermicompost applied in the 4_{th} sowing date, while the lowest one was observed in control in 2_{nd} sowing time (Table 8). Sowing dates and vermicompost doses significantly (0.01) influenced the SET (Table 5). The shortest SET was recorded from 3_{rd} sowing while the longest one was obtained from the last sowing date. Besides, 250 kg da^{-1} vermicompost application encouraged to germination while higher doses caused delaying on the SET. The shortest and longest FT was obtained from 5_{th} and 1_{st} sowings, respectively.

Although 1000 kg da- vermicompost application has significant differences on FT, there is no difference among doses and control. Besides, the interaction of sowing date and vermicompost significantly influenced FT (Table 6). Whereas vermicompost did not influence to PH, sowing dates had significantly (0.01) effects on it. The highest PH was measured in 1_{st} sowings while the shortest one was seen in 2_{nd} sowing (Table 7).

Table 4. Analysis of variance sowing date and vermicompost applications on investigated traits of cv. Fırat-87

Source of variation	DF	NP MS	NP F prob.	NS MS	NS F prob.	SY MS	SY F prob.
Sowing date (S)	4	505.32	**	0.05	ns	32246.1	**
Vermicompost (V)	4	162.62	**	0.10	**	4361.5	**
S x V	16	112.25	**	0.02	*	1575.0	**
	DF	SET MS	SET F prob.	FT MS	FT F prob.	PH MS	PH F prob.
Sowing date (S)	4	309.31	**	5572.45	**	278.82	**
Vermicompost (V)	4	21.98	**	48.55	**	18.88	ns
S x V	16	0.70	ns	27.41	**	31.16	ns

*(**: p<0.01, ns: no significant difference, DF: Degree of freedom, MS: mean of square)*

Discussion

Seedling emergence time

Emergence time extended to hold over with delaying sowings in the winter season. Because, low soil temperature causes to delay the germination time (Nee *et al.*, 2017). Lentil can germinate about 7-8 days at spring sowings where the average temperatures are nearly 20 ºC, emergence may be late up to 25-30 days in winter sowings if the temperatures are lower then 10 ºC (Saxena, 2009). Another factor affecting the germination time is soil moisture. Due to low soil moisture, SET was determined higher in 1_{st} sowing date compared to the 2_{nd} and 3_{rd} times.

Vermicompost has essential and minör nutrients that encourage plant emergence (Ceritoglu *et al.*, 2018). However, vermicompost which has alkaline trait cause to increase pH and electrical conductivity (EC) in soil (Hanc & Vasak, 2015). Also, Rupani *et al.* (2018) stated that high acid concentration and increasing soil pH harmed seed germination. Moreover, the lentil grows better in slightly acidic soil. So, the increase of soil pH inhibited germination and diminish the seedling emergence in lentil.

Table 5. Effect of sowing dates and vermicompost doses on seedling emergence time (day)

Sowing time	Vermicompost (kg da^-) Control	250	500	750	1000	Mean
October 15	14.0	15.0	15.0	16.0	17.3	15.5^b
November 1	12.3	11.3	11.7	12.7	15.0	12.6^c
November 15	11.7	11.0	11.7	12.7	13.7	12.1^c
December 1	14.0	13.3	15.0	15.3	16.3	14.8^b
December 15	23.0	21.3	23.3	24.0	25.3	23.4^a
Mean	15.0^{CD}	14.4^C	15.3^{BC}	16.1^B	17.5^A	
TUKEY $_{(S)}$	1.02**					
TUKEY $_{(V)}$	0.96**					
TUKEY $_{(S \times V)}$	ns					

(Lower case letters were used for grouping of sowing dates while capital letters were used for vermicompost doses)

Flowering time

Flowering time is a vital stage in plant growth that initiates seed production and is vulnerable to stress factors. It was observed that FT decreased depending on delay sowings. The FT in lentil varies depending on genetic properties, day length and ecological conditions (Kahriman *et al.*, 2015). Lentils need to long day length to achieve the generative period which is conducted by some special genes (Welch *et al*., 2005). So, if sowing is delayed, plants achieve long days in less time and FT decrease compared with earlier sowings. Slim *et al*. (1993) stated that FT changed between 114-128 days in late winter sowings and, FT decreased depending on delay sowings in their study.

The earlier flowering and maturity are generally preferred in winter sowings because of second product growth in the same land. However, it is thought that the highest dose of vermicompost adversely affected the lentil and caused stress. So, the lentils extended to early maturity. Because yield components were effected adversely with high doses of vermicompost (Table 8, 9, 10). Arancon *et al*. (2004) stated that high doses of vermicompost have negative effects on plant growth, yield and yield parameters, and explained with the increase of soil pH. The application time of vermicompost was significant and, it was more effective in early sowings than laters because applied vermicompost has dissolved longer time in earlier sowings and more useful for early sown plants.

Table 6. Effect of sowing dates and vermicompost doses on flowering time (day)

	Vermicompost (kg da^{-})					
Sowing time	Control	250	500	750	1000	Mean
October 15	177.3^{ac}	178.7^{ab}	177.3^{ac}	181.7^{a}	178.3^{ab}	178.7^{a}
November 1	167.7^{d}	171.0^{b}	169.3^{b}	169.3^{b}	167.0^{d}	168.9^{b}
November 15	154.3^{e}	154.0^{e}	155.3^{e}	153.7^{e}	153.7^{e}	154.2^{c}
December 1	148.0^{ef}	142.7^{f}	148.0^{ef}	142.7^{f}	131.7^{g}	142.6^{d}
December 15	130.7^{g}	132.7^{g}	131.3^{g}	131.3^{g}	128.7^{g}	130.9^{e}
Mean	155.6^{A}	155.8^{A}	156.3^{A}	155.6^{A}	151.9^{B}	
tukey $_{(S)}$	7.67**					
Tukey $_{(V)}$	2.75**					
Tukey $_{(S\ x\ V)}$	8.43**					

Plant height

Vegetative growth period increases in early sown plants. Generally, vegetative growth and yield increase with early sowing however plant tend to lodging due to high vegetative growth and, cause decrease yield and yield components (Materne & Siddique, 2009). Khatun *et al*. (2016) determined to vary plant height values between 33.6-38.9 cm. Ouji & Mouelhi (2017) stated that variation in plant height fluctuates in the range of 19-35.5 cm and, tended to reduce with delay sowings.

Table 7. Effect of sowing dates and vermicompost doses on plant height (cm)

	Vermicompost (kg da^{-})					
Sowing time	Control	250	500	750	1000	Mean
October 15	53.8	56.8	45.9	57.1	51.1	53.0^{a}
November 1	43.3	39.9	41.8	35.8	45.7	41.3^{b}
November 15	41.1	48.0	43.3	46.2	47.6	46.4^{ab}
December 1	47.0	46.6	45.1	43.1	46.7	45.7^{ab}
December 15	45.2	41.6	45.5	46.9	41.3	44.1^{ab}
Mean	47.3	46.6	44.3	45.8	46.5	
TUKEY $_{(S)}$	9.20*					
TUKEY $_{(V)}$	ns					
TUKEY $_{(S\ x\ V)}$	ns					

Number of pods per plant

The main reason for low pod number in early sowings were lodging and weed problems. Because of excessive vegetative growth, the lodging problem was seen in these plots. Also, although weed management was realized, they rapidly get out on the surface again before winter. Due to its slow-growth physiology, lentil can't compete against weeds (Erman *et al*., 2008). Different researchers stated similar findings and denoted to range from 14.3 to 25.7 (Sen *et al*., 2016; Sözen & Karadavut, 2017).

The reason of negative effect on the NP is thought to be caused by high salinity and pH that originated by high dose of vermicompost (Saket *et al*., 2014). It is estimated that lentil got stressed because plants were exposed to high concentration of vermicompost during the young seedling period.

However, the sufficient dose of vermicompost leads to an increase in root growth and microbial activity in the rhizosphere (Zhang *et al.*, 2020). Also, humic and fulvic acids lead to improve the yield parameters with cause to the dissolving of some components (Wu *et al.*, 2018). Many researchers reported similar findings in their studies (Khan *et al.*, 2017; Hosseinzadeh & Ahmadpour, 2018). According to the interaction, the highest NP was seen on 4_{th} sowing with V2 dose, the lowest one was determined on 2_{nd} sowings in control groups (Table 8).

Table 8. Effect of sowing dates and vermicompost doses on number of pods per plant (plant^{-})

	Vermicompost (kg da^{-})					
Sowing time	Control	250	500	750	1000	Mean
October 15	34.3^{bf}	35.2^{bf}	33.7^{bf}	40.0^{ch}	35.8^{bf}	35.8^{c}
November 1	20.8^{f}	26.7^{ef}	27.9^{df}	31.8^{bf}	39.1^{af}	29.3^{d}
November 15	35.2^{bf}	49.7^{ab}	46.1^{ad}	44.2^{ae}	35.5^{bf}	42.2^{ab}
December 1	45.3^{ad}	47.2^{ac}	54.5^{a}	43.3^{ae}	29.8^{cf}	44.0^{a}
December 15	36.1^{bf}	42.3^{ae}	44.1^{ae}	35.2^{bf}	31.1^{cf}	37.7^{bc}
Mean	34.3^{B}	40.2^{AB}	41.2^{A}	38.9^{AB}	34.3^{B}	
TUKEY $_{(S)}$	5.97**					
TUKEY $_{(V)}$	5.97**					
TUKEY $_{(S \times V)}$	18.33**					

Number of seeds per pod

Some researchers argued that the changes in the number of seeds per plant are caused by genetic properties of used material, however from environmental conditions (Vanave *et al.*, 2019). In contrast, it was stated in the study that because of vermicompost's chemical properties and effects on microbial activity in the rhizosphere, it supports the lentils during the pod filling period. Not only us, some scientists stated that NS is affected not only by genetic factors but also by environmental factors (Aktar *et al.*, 2019). Also, they found to vary NS from 1.73 to 1.93.

The response of plants to ecological conditions, nutrient uptake and physiological growth exhibited differences depending on the sowing date. An adverse effect of V4 dose on NS was determined especially in late sowings because delay sowed plants could not grow rapidly and create an effective root system (Choudhury *et al.*, 2012).

Table 9. Effect of sowing dates and vermicompost doses on the number of seeds per pod (plant^{-1})

	Vermicompost (kg da^{-})					
Sowing time	Control	250	500	750	1000	Mean
October 15	1,29^{ad}	1,45^{ab}	1,32^{ad}	1,41^{ac}	1,26^{ad}	1,35
November 1	1,24^{ad}	1,37^{ad}	1,37^{ad}	1,37^{ad}	1,13^{d}	1,30
November 15	1,13^{d}	1,36^{ad}	1,39^{ad}	1,26^{ad}	1,15^{cd}	1,26
December 1	1,25^{ad}	1,51^{a}	1,51^{a}	1,43^{ab}	1,22^{bd}	1,39
December 15	1,36^{ad}	1,25^{ad}	1,23^{bd}	1,22^{bd}	1,22^{bd}	1,25
Mean	1,25^{BC}	1,39^{A}	1,36^{A}	1,34^{AB}	1,20^{C}	
TUKEY $_{(S)}$	ns					
TUKEY $_{(V)}$	0,09**					
TUKEY $_{(S \times V)}$	0,28*					

Seed yield

The SY was adversely affected for the region if the sowings were delayed later then December 1_{st}. The main reasons for changing in seed yield depending on the sowing date are day length and total temperature. Ghanem *et al.* (2015) stated that the sowing date affects the SY and yield components. Although later sowings enable to increase SY, extra-late sowing leads to a reduction in yield. The main reason for his situation is that the plants sown extra-late could not form an effective root system, therefore, they could not uptake enough water and mineral nutrients.

The SY increased with vermicompost applications because it provided lentil nutrition during the pod-filling period. Also, microbial activity in the rhizosphere increases depending on vermicompost applications (Ahmadpour & Hosseinzadeh, 2017). Vermicompost lead to endorse the proliferation of symbiotic organisms as an activator of mycorrhizal colonization of roots (Cavender *et al.*, 2003) and in the early stage of the crop, moreover, the existence of biologically dynamic substances like plant growth regulators (Huerta *et al*., 2010). Lazcano *et al.* (2013) revealed that vermicompost application has positive effects on microbial community and function (bacterial growth, fungal growth, basal respiration, protease, β-glucosidase and phosphomonoesterase activities), biochemical traits of soil (dissolved organic carbon, total C, N-NH_4^+, N-NO_3^- , PO_4, total K) and crop yield in a short time. Singh *et al.* (2017) determined an increase up to 26% depending on vermicompost doses compared with control. Also, the highest SY was found on 4_{th} sowing with V1 dose while the lowest SY was determined on 2_{nd} sowing with V3 dose. It was estimated that the negative effects of high dose vermicompost in seedling time caused to stress in lentil and reduced the SY.

Table 10. Effect of sowing dates and vermicompost doses on seed yield (kg ha^{-1})

	Vermicompost (kg da^{-})					
Sowing time	Control	250	500	750	1000	Mean
October 15	973^{hi}	974^{hi}	957^{hi}	1212^{ei}	942^{i}	1012^{d}
November 1	982^{gi}	1224^{ei}	1084^{fi}	921^{i}	1030^{gi}	1048^{cd}
November 15	995^{gi}	1502^{bf}	1187^{ei}	1415^{bh}	1243^{di}	1268^{c}
December 1	1449^{bg}	2526^{a}	2518^{a}	2345^{a}	1745^{bc}	2117^{a}
December 15	1706^{bd}	1637^{be}	1763^{b}	1813^{b}	1288^{ci}	1641^{b}
Mean	1221^{B}	1573^{A}	1502^{A}	1541^{A}	1249^{B}	
TUKEY $_{(S)}$	253.9**					
TUKEY $_{(V)}$	152.8**					
TUKEY $_{(S \times V)}$	469.2**					

Conclusions

The findings of the present study suggest that the application of vermicompost has promising short-term effects on crop production. It was determined that the most suitable sowing date for winter lentil production is December 1_{st} for the region. However, late sowings, for example, on December 15_{th}, it has negative impacts on lentil growth. Thus, the proper time for sowings should be ensured in the most suitable time for the region. Also, it was found that low doses of vermicompost application have favorable effects while the high doses inhibit the plant growth and yield parameters. Accordingly, 250 kg da^{-1} vermicompost application is both more economical and effective in terms of seed yield. The highest seed yield was obtained from 250 kg da^{-1} vermicompost applied on 4_{th} sowing time. It is thought that vermicompost application might be a noteworthy alternative, especially for organic production, in lentil cultivation. However, long-term researches are required to understand the residual effect and economic suitability of vermicompost in field conditions.

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