



The Effect of Different Fertilizer and Dose Applications on Grain Yield and Some Crop Characteristics of Oat (*Avena sativa* L.)

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ABSTRACT

In this study, the effects of different organic fertilizer applications (cattle manure, leonardite and seaweed) on grain yield and some plant characteristics of oat (*Avena sativa* L.) were investigated. The oat variety 'Kahraman' was utilized in the experiment. The trial was established in Kahramanmaraş Sütçü İmam University, Faculty of Agriculture Research and Application Area in 2020-21 and 2021-22 growing seasons according to the Bi-level Nested Classification Model trial design with 4 replications. Fertilizer doses were applied as leonardite 50, 100, 150, 200 and 250 kg da⁻¹, cattle manure 1000, 1500, 2000, 2500 and 3000 kg da⁻¹, seaweed 30, 40, 50, 60 and 70 g da⁻¹ and chemical fertilizer pure nitrogen 5, 10, 15, 20 and 25 kg da⁻¹. According to the 2-year average results of the study, it was determined that the differences between the treatments

were statistically significant in the traits examined except ripening time, biological yield and harvest index. Grain yield varied between 264.13-416.29 kg da⁻¹ in the first year, 212.48-449.17 kg da⁻¹ in the second year and the average of the years varied between 238.31-420.73 kg da⁻¹. In the study, the highest grain yield was observed in the first year in chemical fertilizer (CF-3) application, while in the second year and the average of the years, it was obtained in cattle manure (CM-5). It has been determined that cattle manure reached the highest value in terms of grain yield (3000 kg da⁻¹) and seaweed in terms of upper internode length (40 g da⁻¹). It has been observed Cattle manure was found to be superior to chemical fertilizer and other organic fertilizer forms. In this study, it was concluded that cattle manure (3000 kg da⁻¹) dose was the most suitable dose for oat cultivation in Kahramanmaraş ecological conditions.

Keywords: Cattle manure, Seaweed, Leonardite, Organic farming, Oats

1. Introduction

Oat (*Avena sativa* L.), a winter cereal species, is known to be rich in protein, fat, starch, vitamins, and minerals (Flander et al. 2007). Due to its high nutritional value, oat is considered an important cereal species for human and animal nutrition and has been increasingly studied in recent years. Thanks to its nutritional value, oat grains have been strongly recommended for regular consumption in recent studies (Capouchova et al. 2012). Oats also contain various compounds that are beneficial for health, such as vitamins, β -glucans, polyphenols, and unsaturated fatty acids (Van Den Broeck et al. 2016). Oats adapt easily to different soil types and can be grown successfully even in acidic soils (Barsila 2018). Despite favorable environmental conditions for oat cultivation in Türkiye, its production remains limited compared to other cereal crops. In the regions where it is cultivated, chemical fertilizers and pesticides are used. However, this situation poses a risk in terms of sustainable agriculture. Although it increases yield, it also has negative effects, such as leaving residues in agricultural products, polluting the environment, and reducing soil productivity (Gollany et al. 2004; Beman et al. 2005; Zand-Parsa et al. 2006; Kara & Gul 2013; Özdemir 2018; Duran-Lara et al. 2020). This situation may cause the ecological balance to deteriorate and may indirectly have negative effects on human health (Gliessman 2007). Considering these negative effects, alternative methods such as organic agriculture that protect the environment, take care of human health, and ensure the maintenance of soil fertility are needed. The use of organic fertilizers within the scope of organic agriculture has been tested on some plant species and important findings have been revealed. Although oats are among the most important plant crops for human and animal nutrition, sufficient studies have not been conducted on organic fertilization and its effects. Therefore, this study aimed to investigate the effects of organic fertilizers (Leonardite, seaweed, and cattle manure) on grain yield and some agronomic characteristics of oat in Kahramanmaraş ecological conditions. Thus, it is aimed to increase the contribution of organic fertilizer use for the development of oats within the scope of sustainable agriculture.

2. Material and Methods

The research was carried out in Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Field Crops Research and Application Area in the 2020-21 and 2021-22 growing seasons. The "Kahraman" oat variety developed by the Thrace Agricultural Research Institute was used in the study. The climate data for the period in which the experiment was conducted are given in Table 1. When the climate data were examined, it was observed that the total precipitation, mean temperature and minimum temperature were higher in the first year, and the maximum temperature was higher in the second year (Anonymous 2022a).

Table 1- Climate data of Kahramanmaraş province during the period in which the experiment was conducted

Months	Total Precipitation (mm)		Mean Temperature (°C)		Maximum Temperature (°C)		Minimum Temperature (°C)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
November	55.4	15.8	12.4	13.8	25.4	26.8	3.4	6.4
December	56.8	120.8	8.2	7.5	17.0	17.4	-0.9	-3.0
January	211.6	128.0	7.0	4.5	17.4	16.2	-2.3	-7.4
February	29.6	70.6	9.3	8.7	18.7	20.2	-2.3	0.1
March	129.2	99.8	10.4	7.1	21.4	22.2	2.1	-1.8
April	16.8	9.8	16.6	18.2	31.0	31.6	4.6	4.1
May	13.2	28.8	23.5	20.4	36.0	37.0	12.4	10.0
June	0.0	4.0	25.5	26.2	40.4	38.9	14.5	17.2
Total	512.6	477.6	--	--	--	--	--	--
Average	--	--	14.1	13.3	20.9	21.4	4.2	3.2

The soil analysis results of the experimental site are given in Table 2. The soil analysis results of the first year of the experiment, according to the sample taken from 0-30 cm soil depth, the soil texture was clayey-loamy, pH was neutral, non saline, slightly calcareous, organic matter content was moderate, and potassium and phosphorus were sufficient. The soil analysis results of the second year of the experiment determined that the soil texture was clayey-loamy, pH was neutral, non saline, calcareous, organic matter was high, potassium was very low, and phosphorus was at a sufficient level (Anonymous 2022b).

Table 2- Some physical and chemical properties of the experimental site soil

Parameters analyzed	Analysis Results	
	2020-21 Season	2021-22 Season
Saturation (%)	52.8	55.0
pH	6.92	7.27
Salt (%)	0.11	0.10
Lime (%)	0.20	1.59
Organic matter (%)	2.61	3.96
K (mg kg ⁻¹)	218.9	105.4
P (mg kg ⁻¹)	15.14	19.85

The experiment was established using a Bi-level Nested Classification Model trial design with four replications (Efe et al. 2000). The trial plots were planted with a special 6-row seed drill, with 20 cm row spacing and 10 m row length (10 m x 1.2 m = 12 m²) so that 500 seeds per m² would fall. At harvest, the plots were evaluated from a net plot area of 10 m x 1.2 m = 12 m². In the experiment, 4 different fertilizer applications were made, 3 different organic fertilizers (1-Leonardite, 2-Seaweed and 3-Cattle Manure) and 1 chemical fertilizer (Fertilizer doses were determined by taking into account ecological conditions and regional fertilization recommendations). There were 5 different doses of each fertilizer and 21 plots (4 fertilizers x 5 doses + one control) in each block, totalling 84 plots. A 1 m path was left between replications. The doses of fertilizer materials used in the experiment are given in Table 3.

Table 3- Fertilizer material and application doses

Fertilizer Applications	Dose Applications					
	Control	1. Dose	2. Dose	3. Dose	4. Dose	5. Dose
Leonardite (L)	0 kg da ⁻¹	50 kg da ⁻¹	100 kg da ⁻¹	150 kg da ⁻¹	200 kg da ⁻¹	250 kg da ⁻¹
Cattle Manure (CM)	0 kg da ⁻¹	1000 kg da ⁻¹	1500 kg da ⁻¹	2000 kg da ⁻¹	2500 kg da ⁻¹	3000 kg da ⁻¹
Seaweed (S)	0 g da ⁻¹	30 g da ⁻¹	40 g da ⁻¹	50 g da ⁻¹	60 g da ⁻¹	70 g da ⁻¹
Chemical Fertilizer (CF)	0 kg da ⁻¹	5 kg da ⁻¹	10 kg da ⁻¹	15 kg da ⁻¹	20 kg da ⁻¹	25 kg da ⁻¹

Before planting, the trial area was plough at a depth of 25-30 cm. Then, cultivator and roller operations were carried out. After plowing the experimental area, plotting was carried out, and the doses of the fertilizers to be applied before sowing (Leonardite, cattle manure, and chemical fertilizer) were applied in a randomized manner. All doses of cattle manure and leonardite fertilizers

were applied before sowing, while half of the nitrogen fertilizer was applied as DAP (18-46-0) before sowing, and the remaining half as urea (46% N) at the stem elongation stage. Half of the seaweed doses were applied at the beginning of tillering period (during the formation of the 3rd leaf) and the other half during the stemming period with the help of a pulverizer.

The planting of the trials was carried out on November 18, 2020 in the first year and on November 23, 2021 in the second year. After planting, weed control was carried out manually in accordance with organic farming rules on March 10, 2021 in the first year and on April 21, 2022 in the second year. Trial plots were harvested with a parcel combine harvester machine on June 7, 2021, in the 1st year and on June 22, 2022 in the 2nd year.

The examined parameters were measured separately in each plot. In the measurements, 50 cm from the beginning and end of the row of each plot and the first and last rows of the rows were not used. In the study, cluster emergence period (days), flag leaf width (cm), flag leaf length (cm), plant height (cm), upper internode length (cm), ripening time (days), number of fertile tillers (number plant⁻¹), biological yield (kg da⁻¹), grain yield (kg da⁻¹) and harvest index (%) traits were examined. The cluster emergence period was calculated as days from January 1 until 50% of the clusters emerged from the leaf sheath in each plot. During the flowering period, the width of the flag leaf was measured from the middle of the flag leaf on the main stem of 10 plants and the length of the flag leaf was measured starting from the plant stem to the leaf tip. Plant height was measured as the distance from the soil surface to the tip of the terminal spikelet on the main stem in 10 plants per plot. The length between the node from which the flag leaf emerges and the panicle base node was measured as the uppermost internode length. The period from January 1st to 75% full maturity of all plots was evaluated as ripening time. During the harvest period, the number of panicle in 1 meter row was counted and the number of fertile tillers was determined. At harvest time, 6 rows and 1 meter area from the middle of each plot were mowed with a sickle at soil level and weighed and biological yield was calculated by converting to decare. Grain yield of the product harvested with a parcel reaper in 6 rows 10 meters from the middle of all plots was calculated by converting to yield per decare. Harvest index was calculated by dividing the grain yields in each plot measured for biological yield to biological yield. Variance analysis of the experiment and comparison of means were performed in SPSS Statistics package program.

3. Results and Discussion

Statistically significant differences ($P < 0.01$) were detected between the years and the means in terms of cluster period (Table 4). This situation showed that fertilizer applications significantly affected the earliness or lateness in cluster period. When the data of both years and the years' means were taken into consideration, it was determined that cattle manure and chemical fertilizer applications encouraged earliness in terms of cluster period. Earliness was observed in the CM-5 (110.5 days) application with cattle manure during the cluster period. The latest cluster formation time was observed in the control (113.88 days) application (Table 4).

Table 4- Average values and groups of the effects of fertilizer doses on cluster emergence period (days) and flag leaf width (cm) in the 2020-21 and 2021-22 trial seasons

Application	Cluster Emergence Period (days)						Flag Leaf Width (cm)					
	2020-21		2021-22		Average and Groups		2020-21		2021-22		Average and Groups	
Control	108.25	± 0.48	119.50	± 0.87	113.88	± 2.17 A	1.24	± 0.03	0.95	± 0.05	1.10	± 0.06 G
CM-1	107.75	± 0.63	116.00	± 0.00	111.88	± 1.59 CG	1.32	± 0.04	1.25	± 0.10	1.29	± 0.05 EF
CM-2	107.75	± 0.48	115.75	± 0.25	111.75	± 1.53 CG	1.33	± 0.03	1.20	± 0.11	1.27	± 0.06 FG
CM-3	107.25	± 0.48	115.25	± 0.25	111.25	± 1.53 FH	1.42	± 0.05	1.15	± 0.07	1.28	± 0.06 EG
CM-4	106.75	± 0.48	115.25	± 0.25	111.00	± 1.63 GH	1.51	± 0.04	1.29	± 0.07	1.40	± 0.06 CF
CM-5	106.25	± 0.25	114.75	± 0.48	110.50	± 1.63 H	1.64	± 0.03	1.42	± 0.11	1.53	± 0.07 AD
L-1	108.50	± 0.65	117.75	± 0.48	113.13	± 1.79 AB	1.38	± 0.07	1.12	± 0.06	1.25	± 0.06 FG
L-2	108.75	± 0.25	117.75	± 0.48	113.25	± 1.72 AB	1.50	± 0.14	1.19	± 0.09	1.35	± 0.09 DF
L-3	108.00	± 0.71	116.75	± 0.48	112.38	± 1.70 BF	1.52	± 0.05	1.17	± 0.10	1.34	± 0.08 EF
L-4	108.00	± 0.41	117.25	± 0.85	112.63	± 1.80 BE	1.38	± 0.02	1.32	± 0.17	1.35	± 0.08 DF
L-5	108.00	± 0.00	116.75	± 0.48	112.38	± 1.67 BF	1.49	± 0.06	1.81	± 0.28	1.65	± 0.15 AB
S-1	108.25	± 0.63	118.25	± 1.03	113.25	± 1.97 AB	1.39	± 0.12	1.20	± 0.05	1.29	± 0.07 EF
S-2	107.25	± 0.25	118.25	± 1.03	112.75	± 2.14 AD	1.37	± 0.09	1.23	± 0.08	1.30	± 0.06 EF
S-3	107.25	± 0.48	118.50	± 0.87	112.88	± 2.17 AC	1.50	± 0.03	1.30	± 0.08	1.40	± 0.06 CF
S-4	107.00	± 0.41	117.75	± 0.75	112.38	± 2.07 BF	1.48	± 0.05	1.25	± 0.10	1.37	± 0.07 DF
S-5	106.75	± 0.25	117.50	± 0.87	112.13	± 2.07 BG	1.48	± 0.05	1.33	± 0.08	1.41	± 0.05 CF
CF-1	107.75	± 0.48	116.00	± 1.00	111.88	± 1.64 CG	1.69	± 0.03	1.25	± 0.15	1.47	± 0.11 BE
CF-2	107.75	± 0.48	115.25	± 0.48	111.50	± 1.45 EH	1.82	± 0.04	1.31	± 0.05	1.56	± 0.10 AC
CF-3	107.50	± 0.96	114.75	± 0.48	111.13	± 1.46 GH	1.79	± 0.16	1.37	± 0.10	1.58	± 0.12 AC
CF-4	108.50	± 1.04	114.75	± 0.48	111.63	± 1.29 DH	1.94	± 0.13	1.46	± 0.12	1.70	± 0.12 A
CF-5	108.50	± 1.26	114.50	± 0.29	111.50	± 1.28 EH	1.88	± 0.09	1.41	± 0.06	1.64	± 0.10 AB
Average	107.70	± 0.13	116.58	± 0.20	112.14	± 0.36	1.53	± 0.03	1.28	± 0.03	1.41	± 0.02

LSD 5%: 1.23, CV%: 1.11, F value: year: 2140.446**, application: 3.440**, ** Significant at P<0.01 level.

LSD5%: 0.19, CV%: 13.54, F value: year: 67.504**, application: 3.578**, ** Significant at P<0.01 level.

Mason et al. (2007) reported that earliness reduced weed density in their study under organic farming conditions. Özkan & Akıncı (2021) found that wheat genotypes grown under organic and conventional conditions developed earlier in the organic system. Similarly, Bleidere et al. (2011) reported that the cluster emergence period was shorter in oat genotypes grown under organic and conventional farming conditions (54 days) under organic conditions. The findings in the literature are also parallel to our findings.

In terms of flag leaf width, statistically significant differences ($P < 0.01$) were determined between the years and applications in which the experiment was conducted (Table 4). This result reveals that fertilizer applications have a significant effect on flag leaf width, which is an indicator of photosynthetic area. When the 1st year, 2nd year and the average of the years are considered, it is seen that chemical fertilizer applications increase the flag leaf width more than the other applications. The highest flag leaf width was seen in the CF-4 (1.70 cm) application with chemical fertilizer. When the average of the years is considered, the lowest flag leaf width was determined in the control application (1.10 cm) (Table 4).

Table 5- Average values and groups of the effects of fertilizer doses on flag leaf length (cm) and plant height (cm) in the 2020-21 and 2021-22 trial seasons

Application	Flag Leaf Length (cm)						Plant Height (cm)					
	2020-21		2021-22		Average and Groups		2020-21		2021-22		Average and Groups	
Control	11.30	± 0.43	10.03	± 0.31	10.66	± 0.34F	96.20	± 0.41	76.85	± 0.89	86.53	± 3.68F
CM-1	11.74	± 0.88	13.34	± 0.81	12.54	± 0.63CE	101.46	± 2.13	91.77	± 4.55	96.61	± 2.96DF
CM-2	11.54	± 0.75	12.78	± 0.99	12.16	± 0.62DF	104.00	± 2.81	94.73	± 3.25	99.36	± 2.65CF
CM-3	12.68	± 0.64	12.87	± 1.01	12.77	± 0.56CE	107.22	± 2.46	95.30	± 3.47	101.26	± 2.99BE
CM-4	13.73	± 0.97	13.72	± 1.06	13.72	± 0.67BD	105.34	± 1.69	121.77	± 2.03	113.55	± 1.58AB
CM-5	13.55	± 0.53	13.85	± 1.02	13.70	± 0.53BE	107.90	± 2.42	101.58	± 0.90	104.74	± 1.69BE
L-1	12.46	± 1.25	11.59	± 0.77	12.02	± 0.70EF	103.59	± 2.65	89.51	± 4.28	96.55	± 3.54DF
L-2	12.54	± 1.18	13.88	± 1.05	13.21	± 0.77CE	102.87	± 2.76	91.86	± 3.67	97.36	± 2.98DF
L-3	13.16	± 0.68	13.16	± 0.99	13.16	± 0.55CE	103.31	± 1.96	91.11	± 2.61	97.21	± 2.76DF
L-4	12.73	± 0.96	14.85	± 1.24	13.79	± 0.83BD	102.68	± 2.32	94.61	± 1.37	98.65	± 1.97DF
L-5	13.92	± 0.64	14.19	± 0.52	14.06	± 0.38BC	99.03	± 4.12	95.96	± 1.61	97.49	± 2.13DF
S-1	11.61	± 0.53	13.50	± 0.20	12.56	± 0.44CE	100.06	± 1.91	84.74	± 3.10	92.40	± 3.35EF
S-2	11.68	± 0.42	13.60	± 0.82	12.64	± 0.56CE	103.36	± 2.39	87.02	± 3.19	95.19	± 3.60DF
S-3	12.67	± 0.39	14.03	± 0.83	13.35	± 0.50BE	104.33	± 2.10	88.23	± 3.09	96.28	± 3.50DF
S-4	12.69	± 0.33	14.41	± 0.93	13.55	± 0.56BE	103.53	± 1.84	111.28	± 2.26	107.40	± 9.99BD
S-5	12.70	± 0.57	14.74	± 0.14	13.72	± 0.47BD	103.05	± 1.88	91.17	± 1.95	97.11	± 2.57DF
CF-1	14.37	± 0.33	12.84	± 1.27	13.61	± 0.67BE	106.53	± 1.74	89.96	± 1.05	98.25	± 3.27DF
CF-2	16.95	± 0.42	13.02	± 0.57	14.98	± 0.81B	110.50	± 3.13	93.38	± 2.63	101.94	± 3.75BE
CF-3	21.81	± 2.62	14.43	± 0.59	18.12	± 1.87A	113.81	± 1.99	97.89	± 0.91	105.85	± 3.17BD
CF-4	19.14	± 0.48	15.67	± 0.54	17.40	± 0.74A	121.87	± 0.54	123.72	± 2.75	122.80	± 1.46A
CF-5	18.98	± 0.27	14.77	± 0.26	16.87	± 0.81A	123.32	± 2.74	100.56	± 0.36	111.94	± 4.49AC
Average	13.90	± 0.35	13.58	± 0.20	13.74	± 0.20	105.90	± 0.84	95.86		100.88	± 1.20
LSD5%: 1.69, CV%: 12.45, F value: year: 1.471 NS, application: 6.635**, ** Significant at P<0.01 level, NS: Not Significant							LSD5%: 13.26, CV%: 13.28, F value: year: 23.595**, application: 1.909**, ** Significant at P<0.01 level					

Studies have shown that flag leaf width can show significant differences depending on genotypes and environmental conditions. Semchenko & Zobel (2005) detected significant differences in flag leaf width among oat genotypes. Dere & Yıldırım (2006) reported that flag leaf width is a statistically significant trait in bread wheat. Aktaş (2010) stated that flag leaf width shows significant differences among bread wheat genotypes and that this varies depending on climatic conditions and genotype characteristics. Bleidere et al. (2011) reported that flag leaf width was higher in organic systems in oat genotypes grown under organic and conventional conditions. Geçit (2016) emphasized that the flag leaf on the plant is an important organ in terms of nutrients accumulated in the grain. Zhao et al. (2022) evaluated flag leaf width as an important morphological trait in terms of production in their study on bread wheat.

No statistically significant difference was found among the years in terms of flag leaf length. However, significant ($P < 0.01$) differences were found among the applications in terms of flag leaf length within the years (Table 5). These findings show that fertilizer applications have a significant effect on flag leaf length, and therefore in terms of photosynthetic area. As a result of the evaluation made by considering the 1st year, 2nd year and year averages, it was determined that chemical fertilizer applications were more effective in increasing flag leaf length compared to other applications according to the 1st year and average values, and chemical fertilizer and seaweed applications in the 2nd year were more effective than other applications. The highest flag leaf length was observed in the CF-3 (18.12 cm), CF-4 (17.40 cm) and CF-5 (16.87 cm) applications of chemical fertilizer. The lowest flag leaf length according to the year average was measured in the control (10.66 cm) application (Table 5). Dere & Yıldırım (2006) reported that flag leaf length was a statistically significant trait in their study on bread wheat varieties. Yolcu (2008), in his study conducted in Kelkit conditions of Gümüşhane province, stated that control and 2 t da⁻¹ barnyard manure

applied to barley and wheat varieties had significant effects on flag leaf length, and also stated that organic-origin barnyard manure reduced flag leaf length, and the highest flag leaf length in barley and wheat was detected in the wheat plant in the control application with 5.40 cm. Bleidere et al. (2011) observed that flag leaf length was higher in organic conditions in oat genotypes grown in organic and conventional conditions. Geçit (2016) stated that the flag leaf is an important organ in terms of nutrients accumulated in the grain and its length can be evaluated as an important effect in terms of grain yield. These results clearly show that flag leaf length can vary depending on the genotype, environmental conditions and the type of fertilizer applied.

Table 6- Average values and groups of the effects of fertilizer doses on upper internode length (cm) and ripening time (days) in the 2020-21 and 2021-22 trial seasons

Application	Upper internode Length (cm)						Ripening Time (days)					
	2020-21		2021-22		Average and Groups		2020-21		2021-22		Average and Groups	
Control	24.67	± 0.13	25.25	± 0.59	24.96	± 0.30G	144.75	± 0.25	152.75	± 0.48	148.75	± 1.53
CM-1	24.65	± 0.18	33.60	± 1.21	29.12	± 1.78CF	144.75	± 0.25	151.50	± 0.65	148.13	± 1.32
CM-2	27.85	± 0.28	33.66	± 0.60	30.76	± 1.14AB	144.75	± 0.25	152.00	± 0.41	148.38	± 1.39
CM-3	27.76	± 0.44	34.02	± 1.30	30.89	± 1.34AB	144.50	± 0.29	152.00	± 0.58	148.25	± 1.45
CM-4	27.61	± 0.68	34.05	± 0.52	30.83	± 1.28AB	144.50	± 0.29	152.00	± 0.91	148.25	± 1.49
CM-5	27.21	± 0.76	34.50	± 0.75	30.85	± 1.46AB	144.50	± 0.29	152.25	± 0.48	148.38	± 1.49
L-1	26.13	± 0.44	30.64	± 0.60	28.38	± 0.92EF	144.50	± 0.29	152.25	± 0.85	148.38	± 1.52
L-2	26.76	± 0.58	32.63	± 1.09	29.69	± 1.25BE	144.50	± 0.29	152.25	± 0.48	148.38	± 1.49
L-3	26.21	± 0.62	33.03	± 1.26	29.62	± 1.44BE	144.50	± 0.29	152.00	± 0.91	148.25	± 1.49
L-4	26.18	± 0.08	34.44	± 0.66	30.31	± 1.59AD	144.50	± 0.50	152.75	± 0.48	148.63	± 1.59
L-5	25.88	± 0.46	33.98	± 0.86	29.93	± 1.60AE	144.50	± 0.29	152.75	± 0.48	148.63	± 1.58
S-1	26.74	± 0.57	32.80	± 0.86	29.77	± 1.24AE	144.50	± 0.29	152.75	± 0.48	148.63	± 1.58
S-2	28.41	± 0.34	34.11	± 1.46	31.26	± 1.28A	144.25	± 0.25	160.00	± 6.67	152.13	± 4.29
S-3	27.42	± 0.58	33.59	± 1.25	30.50	± 1.33AC	144.25	± 0.25	153.25	± 0.85	148.75	± 1.75
S-4	27.40	± 0.13	32.35	± 1.32	29.88	± 1.12AE	144.00	± 0.00	152.50	± 0.96	148.25	± 1.67
S-5	25.94	± 0.42	31.87	± 0.61	28.90	± 1.17DF	144.25	± 0.25	153.00	± 1.22	148.63	± 1.75
CF-1	27.00	± 0.60	32.89	± 1.17	29.94	± 1.27AE	144.50	± 0.29	152.75	± 0.85	148.63	± 1.61
CF-2	25.53	± 0.48	32.25	± 1.07	28.89	± 1.38DF	144.75	± 0.48	151.00	± 1.00	147.88	± 1.29
CF-3	24.86	± 0.62	33.25	± 0.74	29.05	± 1.65CF	145.00	± 0.41	151.00	± 1.00	148.00	± 1.24
CF-4	24.40	± 0.61	31.66	± 1.54	28.03	± 1.57F	146.00	± 0.00	152.75	± 0.85	149.38	± 1.34
CF-5	24.41	± 0.43	30.97	± 0.36	27.69	± 1.27F	145.75	± 0.25	152.25	± 1.11	149.00	± 1.34
Average	26.33	± 0.16	32.64	± 0.29	29.49	± 0.29	144.64	± 0.08	152.65	± 0.37	148.65	± 0.36
LSD5%: 1.56, CV%: 5.35, F value: year: 672.664**, application: 4.491**, ** Significant at P<0.01 level							LSD5%: 2.34, CV%: 1.59, F value: year: 480.987**, Application: 4.491 NS, ** Significant at P<0.01 level, NS: Not Significant					

Statistically significant ($P<0.01$) differences were determined between the experimental years and fertilizer applications in terms of plant height (Table 5). This situation shows that fertilizer applications have a significant effect on plant height. While the highest plant height was obtained in chemical fertilizer applications according to the 1st year and the average of the years, it was observed that cattle manure applications in addition to chemical fertilizer increased plant height in the 2nd year. The longest plant height was determined in the CF-4 application with chemical fertilizer (122.80 cm). On the other hand, the shortest plant height according to the average of the years was observed in the control (86.53 cm) application (Table 5). The findings regarding plant height are largely consistent with previous studies. Bleidere et al. (2011) stated that plant height in oat genotypes was higher in organic conditions than in conventional methods. Kodas et al. (2015) and Bayhan (2021) reported that plant height in bread wheat genotypes was shorter in organic farming conditions than in conventional conditions. This situation can be explained by the fact that plant height in different species and genotypes varies according to environmental conditions. Özkan & Akıncı (2021) reported that 37.5% of the genotypes showed longer plant height in organic farming in wheat genotypes under organic and conventional farming conditions. Ataman (2022), who investigated the relationship between plant height and nitrogen doses, reported that an increase in nitrogen application increased plant height proportionally. Similarly, Hocaoglu (2020) reported that plant height in oat varieties applied with different nitrogen doses (0, 5, 10, 15, 20 kg N da⁻¹) varied between 124 cm and 136 cm, and that plant height increased with the increase in nitrogen doses. In his study, Sobayoğlu (2017) determined the plant height in oat varieties to be between 54.60 and 72.80 cm; the fact that these values were lower than the values determined in our study may have been due to the effects of the applied fertilizer forms and environmental differences. Kolay et al. (2016), who investigated the effect of leonardite application, determined that leonardite applied at different doses in wheat increased plant height from 98.16 cm (control) to 100.53 cm, and these results support the findings of our study. Shan et al. (2013) investigated the effects of liquid seaweed extracts on plant height in wheat and stated that *K. alvarezii* seaweed applied at a dose of 7.5% provided the longest plant height with 83.60 cm. This finding shows that seaweed can also contribute to plant development. In addition, Mason et al. (2007) stated that plant height increased under organic conditions and that tall plants provided ecological benefits by suppressing weed biomass. When these studies are evaluated in general, it is seen that different fertilizer forms and application methods significantly affect plant height in oat plants. In our study, it is understood that in addition to chemical fertilizers, applications from organic materials also have positive effects on plant height (Table 5).

Statistically significant ($P<0.01$) differences were determined between the years in which the experiment was conducted and the fertilizer applications in terms of the upper internode length (Table 6). It shows that fertilizer applications are effective on the upper internode length, which is one of the subcomponents of plant height. In terms of upper internode length, seaweed applications were more effective in the 1st year, whereas cattle manure applications showed greater effectiveness in the 2nd year and in the overall average of the years. The application with the highest upper internode length was obtained in the S-2 application of seaweed (31.26 cm). In the average of the years in which the experiment was conducted, it was observed that the control (24.96 cm) reached the shortest upper internode length (Table 6). In the study, Çalışkan & Koç (2019) reported that oat genotypes showed statistically significant differences in terms of upper internode length. Panozzo et al. (2020) stated that planting wheat in olive orchards under organic conditions increased the upper internode length. Karakuzu (2022) determined the shortest upper internode length at 8 kg da⁻¹ nitrogen dose (27.5 cm) in different nitrogen doses (0, 4, 8, 12 and 16 kg da⁻¹) applied to Kahraman oat variety.

Although it was determined that there were statistically significant differences ($P<0.01$) between the years in which the experiment was conducted in terms of ripening time, no significant difference was detected between the applications depending on the years in terms of ripening time (Table 6). However, cattle manure and chemical fertilizer applications showed earlier maturation ripening compared to the other treatments, although the differences were not statistically significant. The earliest ripening occurred in the CF-2 application of the chemical fertilizer application with 147.88 days. The latest ripening time according to the average of the years was determined as 152.13 days in the S-2 variant of the seaweed application (Table 6). In previous studies, Gursoy (2011) reported that different nitrogen doses in barley genotypes did not have a statistically significant effect on ripening time. Olesen et al. (2012) emphasized that ripening time in oat plants varies depending on environmental factors such as day length, temperature and physiological stress. Kececioğlu et al. (2021) stated that ripening time in different oat genotypes showed statistically significant differences over the years. Özkan & Akıncı (2021) determined that wheat genotypes grown under organic conditions ripened earlier compared to conventional conditions. Öncan Sümer (2008), in his study where he applied different nitrogen doses and different planting frequencies in wheat, determined that the longest ripening time occurred at a nitrogen dose of 16 kgNda⁻¹ and a density of 700 plant m⁻². These studies show that ripening time is significantly affected by both genetic and environmental factors. Thus, it reveals that ripening time is an important agricultural feature that directly affects the development process and harvest time of plants.

Table 7- Average values and groups of the effects of fertilizer doses on the number of fertile tillers (number) and biological yield (kg da⁻¹) in the 2020-21 and 2021-22 trial seasons

Application	Number of Fertile Tillers (number plant ⁻¹)						Biological Yield (kg da ⁻¹)					
	2020-21		2021-22		Average and Groups		2020-21		2021-22		Average and Groups	
Control	2.56	± 0.12	2.37	± 0.09	2.46	± 0.08 G	872.92	± 73.43	812.71	± 61.19	842.81	± 45.69
CM-1	2.68	± 0.17	2.95	± 0.05	2.81	± 0.10 EG	1105.63	± 125.08	1074.58	± 93.26	1090.10	± 72.46
CM-2	2.68	± 0.15	3.18	± 0.20	2.93	± 0.15 EF	1162.50	± 159.04	1025.42	± 63.15	1093.96	± 83.34
CM-3	2.95	± 0.13	3.83	± 0.38	3.39	± 0.25 AD	1088.19	± 69.36	1027.50	± 64.39	1057.84	± 45.29
CM-4	2.80	± 0.20	3.58	± 0.31	3.19	± 0.23 AE	1130.77	± 123.70	1185.83	± 27.09	1158.30	± 59.54
CM-5	2.90	± 0.10	3.58	± 0.26	3.24	± 0.18 AE	1137.29	± 72.11	1224.17	± 124.57	1180.73	± 68.62
L-1	2.90	± 0.20	2.98	± 0.23	2.94	± 0.14 EF	1017.60	± 106.30	837.50	± 105.42	927.55	± 77.21
L-2	3.23	± 0.05	3.00	± 0.08	3.11	± 0.06 BE	1260.73	± 176.81	850.00	± 100.62	1055.36	± 122.04
L-3	3.08	± 0.17	3.38	± 0.21	3.23	± 0.14 AE	1275.00	± 58.09	949.17	± 25.29	1112.08	± 68.20
L-4	2.75	± 0.33	3.60	± 0.27	3.18	± 0.25 AE	1206.67	± 105.92	1088.75	± 106.58	1147.71	± 73.04
L-5	2.73	± 0.14	3.45	± 0.20	3.09	± 0.18 CF	1079.79	± 85.57	1018.34	± 58.13	1049.06	± 49.28
S-1	2.65	± 0.23	2.68	± 0.11	2.66	± 0.12 FG	1194.79	± 136.05	833.33	± 95.59	1014.06	± 102.91
S-2	2.85	± 0.42	2.78	± 0.13	2.81	± 0.20 EG	1197.19	± 132.27	828.96	± 74.14	1013.07	± 98.84
S-3	3.08	± 0.34	2.58	± 0.11	2.83	± 0.19 EG	1145.10	± 177.81	1069.17	± 100.57	1107.14	± 95.64
S-4	2.98	± 0.21	3.03	± 0.08	3.00	± 0.10 DF	1144.27	± 192.97	879.58	± 120.09	1011.93	± 116.50
S-5	2.98	± 0.18	3.03	± 0.11	3.00	± 0.10 DF	964.38	± 146.40	974.17	± 151.16	969.27	± 97.43
CF-1	3.08	± 0.35	3.00	± 0.31	3.04	± 0.22 CF	1102.09	± 113.03	1112.08	± 189.64	1107.08	± 102.21
CF-2	3.15	± 0.17	3.00	± 0.19	3.08	± 0.12 CF	1313.02	± 150.41	962.50	± 48.04	1137.76	± 98.64
CF-3	3.15	± 0.26	3.35	± 0.18	3.25	± 0.15 AE	1323.44	± 188.71	1037.71	± 26.90	1180.57	± 103.45
CF-4	3.30	± 0.41	3.83	± 0.16	3.56	± 0.23 A	1270.73	± 64.72	1017.92	± 131.36	1144.32	± 82.93
CF-5	3.48	± 0.31	3.63	± 0.21	3.55	± 0.18 AB	989.17	± 39.61	1264.58	± 125.24	1126.87	± 80.04
Average	2.95	± 0.05	3.18	± 0.06	3.06	± 0.04	1141.96	± 27.22	1003.52	± 23.60	1072.74	± 18.74
LSD5%: 0.44, CV%: 14.60, F value: year: 11.105**, application: 2.235**, **Significant at P<0.01 level							LSD5%: 225.76, CV%: 21.27, F value: year: 15.464**, application: 1.196 NS, ** Significant at P<0.01 level, NS: Not Significant					

Statistically significant ($P<0.01$) differences were determined between the years and applications in which the experiment was conducted in terms of fertile tiller number. (Table 7). This situation shows that fertilizer applications have a significant effect on fertile tiller number. When the 1st year and the average of the years are considered, it was determined that chemical fertilizer applications increased the fertile tiller number; in the 2nd year, both cattle manure and chemical fertilizer applications were more

effective than other applications. The highest fertile tiller number was obtained with 3.56 units in the CF-4 application of chemical fertilizer. According to the average of the years, the lowest fertile tiller number was observed in the control application with 2.46 units (Table 7). In the studies, Çobanoğlu & Ayrancı (2021) determined that nitrogen applications caused statistically significant differences on the number of fertile tillers per square meter by applying nitrogen fertilizer to bread wheat varieties at different times and different doses. In addition, m² the number of fertile tillers was determined as 236.9 in the control application at least and 293.5 in the nitrogen dose of 4.65 kg da⁻¹ applied at the beginning of stem elongation

It was determined that there was a statistically significant difference ($P < 0.01$) between the years in which the experiment was conducted in terms of biological yield (Table 7). However, no significant difference was found between the applications in terms of biological yield in both years. This situation shows that the effect of fertilizer applications on biological yield is limited. When evaluated according to annual data and yearly averages, it was revealed that cattle manure and chemical fertilizer applications were more effective than other applications in terms of biological yield (Table 7). Kudas et al. (2015) reported that biological yield showed statistically significant changes in organic fertilizer forms applied to different wheat genotypes. In addition, the highest biological yield was obtained in chemical fertilizer application with 1632.6 g, while the lowest biological yield was obtained in barn manure application with 835.6 g. In a study conducted by Nasiroleslami et al. (2021), different nitrogen doses (0, 75, 150 and 225 kg N ha⁻¹), humic acid (2 kg ha⁻¹), seaweed extract (4 L ha⁻¹) and combinations of these two (HA+SE) applied to wheat plants were examined. In their research, the highest biological yield was obtained at a nitrogen dose of 150 kg N ha⁻¹, in humic acid and humic acid+seaweed applications.

Table 8- Average values and groups of the effects of fertilizer doses on grain yield (kgda⁻¹) and harvest index (%) in the 2020-21 and 2021-22 trial seasons

Application	Grain Yield (kg da ⁻¹)						Harvest Index (%)					
	2020-21		2021-22		Average and Groups		2020-21		2021-22		Average and Groups	
Control	264.13	± 21.92	212.48	± 9.62	238.31	± 14.77 E	30.97	± 3.79	26.36	± 1.06	28.67	± 2.02
CM-1	340.26	± 40.63	346.17	± 16.98	343.21	± 20.42 BD	30.96	± 2.85	32.89	± 3.04	31.92	± 1.96
CM-2	364.03	± 30.75	354.50	± 15.39	359.26	± 16.02 BD	32.50	± 3.43	35.15	± 3.36	33.82	± 2.28
CM-3	373.61	± 6.79	361.40	± 17.79	367.50	± 9.11 BC	32.97	± 1.77	37.59	± 4.26	35.28	± 2.31
CM-4	383.40	± 19.88	366.13	± 8.32	374.76	± 10.50 B	34.83	± 2.98	30.10	± 1.93	32.47	± 1.87
CM-5	392.29	± 7.52	449.17	± 36.26	420.73	± 20.23 A	34.91	± 2.26	37.59	± 3.92	36.25	± 2.16
L-1	361.34	± 27.73	307.46	± 28.69	334.40	± 21.09 BD	36.53	± 4.22	37.80	± 3.87	37.16	± 2.66
L-2	364.46	± 6.92	323.04	± 23.34	343.75	± 13.72 BD	28.79	± 3.21	38.66	± 2.33	33.72	± 2.62
L-3	371.70	± 36.43	319.79	± 16.90	345.74	± 21.02 BD	33.55	± 5.60	33.78	± 2.17	33.67	± 2.78
L-4	367.07	± 26.52	328.38	± 13.38	347.72	± 15.58 BD	30.69	± 1.96	30.96	± 2.87	30.82	± 1.61
L-5	345.09	± 19.85	348.33	± 9.10	346.71	± 10.13 BD	32.27	± 2.04	34.54	± 2.09	33.41	± 1.42
S-1	361.82	± 22.57	301.13	± 22.73	331.47	± 8.74 CD	31.97	± 4.99	37.26	± 4.08	34.61	± 3.14
S-2	368.95	± 14.63	313.71	± 17.71	341.33	± 14.90 BD	30.29	± 4.60	41.06	± 1.15	35.67	± 2.99
S-3	379.56	± 24.67	328.65	± 18.96	354.10	± 17.32 BD	36.96	± 8.85	29.64	± 4.12	33.30	± 4.73
S-4	384.53	± 20.61	326.59	± 12.51	355.56	± 15.64 BD	36.56	± 6.36	37.95	± 6.05	37.25	± 4.07
S-5	347.67	± 15.85	346.29	± 18.51	346.98	± 11.28 BD	38.28	± 5.08	37.66	± 4.96	37.97	± 3.29
CF-1	400.22	± 40.67	327.21	± 13.61	363.71	± 24.18 BD	36.38	± 1.59	31.50	± 4.07	33.94	± 2.22
CF-2	409.92	± 25.80	329.84	± 10.55	369.88	± 19.89 BC	32.36	± 3.81	34.61	± 2.50	33.48	± 2.15
CF-3	416.29	± 21.76	331.08	± 8.29	373.69	± 19.38 BC	33.77	± 6.11	40.04	± 9.26	36.91	± 5.27
CF-4	361.72	± 23.03	328.59	± 7.52	345.15	± 12.84 BD	28.90	± 3.02	34.34	± 5.41	31.62	± 3.05
CF-5	340.22	± 15.64	308.79	± 20.80	324.50	± 13.43 D	34.40	± 0.97	25.44	± 3.60	29.92	± 2.42
Average	366.58	± 5.72	331.37	± 5.58	348.97	± 4.21	33.28	± 0.85	34.52	± 0.90	33.90	± 0.62
LSD5%: 42.28, CV%: 12.24, F value: year: 28.530**, application: 2.944**, **							LSD5%: 8.18, CV%: 24.38, F value: year: 0.948 NS, application: 0.751 NS, NS: Not Significant					

It was determined that there were statistically significant ($P < 0.01$) differences between the years and applications in which the experiment was conducted in terms of grain yield. This situation reveals that the effects of fertilizer applications on grain yield are important (Table 8). According to the 1st year, 2nd year and the average of the years, it was observed that cattle manure and chemical fertilizer applications had a positive effect on grain yield. The highest grain yield was obtained as 420.73 kg da⁻¹ in the CM-5 application of cattle manure. On the other hand, the lowest grain yield was determined as 238.31 kg da⁻¹ in the control application (Table 8). Nawaz et al. (2004) reported that grain yield in oat varied significantly among varieties. Öztürk et al. (2012) determined in their study conducted in Erzurum conditions in wheat that NP fertilizer gave the highest result in terms of grain yield and that among organic fertilizers, cattle manure increased the yield by 25.60% compared to the control group. Kara & Gül (2013) evaluated the effects of organic fertilizer applications applied to wheat genotypes on grain yield in their study conducted in Isparta ecological conditions. In our study, while the highest grain yield was obtained with conventional fertilizer application as 384.70 kg da⁻¹, the lowest grain yield was obtained with seaweed application as 166.70 kg da⁻¹. As a result of the study, it was reported that grain yield in cattle manure applications varied between 210.7–213.0 kg da⁻¹ and they suggested that cattle manure is a suitable alternative for organic wheat cultivation in the regional conditions. Shan et al. (2013) found that liquid seaweed obtained from *K. alvarezii* and *G. edulis* species applied to wheat plants provided the highest grain yield (4.55 t ha⁻¹) at

a dose of 7.5%. Kolay et al. (2016) investigated the effects of leonardite applied to soil at different doses on wheat grain yield and according to the results of the research, the highest yield was obtained at a dose of 749.70 kg da⁻¹ (50 kg da⁻¹) and the lowest yield was obtained at a dose of 635.84 kg da⁻¹ (250 kg da⁻¹). Ma et al. (2017), in their study conducted under Canadian conditions, found that yield increased in parallel with nitrogen doses of 0, 50, 100 and 150 kg N ha⁻¹ applied to oat varieties; They reported that the highest yield was 5953 kg ha⁻¹ at a dose of 150 kg N ha⁻¹ and 5605 kg ha⁻¹ at a dose of 100 kg N ha⁻¹. Vateva & Trendafilov (2016) reported that the Mina oat variety increased grain yield in an ecological environment without the use of mineral fertilizers or pesticides in Bulgaria and the Sakar region. They found that the average oat yield in Bulgaria was 1745 kg ha⁻¹, while in the Sakar region, the average oat yield was 1263 kg ha⁻¹.

In the study, no statistically significant difference was found between the years in which the experiment was conducted and the applications in terms of harvest index (Table 8). This shows that fertilizer applications do not have a significant effect on the harvest index. However, according to the average of the years, it can be said that cattle manure, leonardite and seaweed applications are more effective than other applications (Table 8). In previous studies, it has been reported that harvest index can vary depending on plant species and genotype characteristics. In particular, Kodas et al. (2015) reported that organic fertilizer applications applied to wheat genotypes had statistically significant effects on harvest index and that conventional fertilizer applications gave higher harvest index values compared to barnyard manure applications. In the study, it was reported that harvest index was at the highest level with 30.9% in conventional application and at the lowest level with 25.1% in barnyard manure application. Çiftçi et al. (2016) determined that there were no statistically significant differences between genotypes in harvest index in oat genotypes.

4. Conclusions

In this study, the effects of different forms of organic fertilizers (leonardite, seaweed, and cattle manure) on grain yield and several agronomic traits of oat were investigated under the ecological conditions of Kahramanmaraş. According to the data obtained, significant differences were found among treatments for all characteristics except for ripening period, biological yield, and harvest index. While chemical fertilizer applications showed superiority in certain traits (flag leaf width, flag leaf length, and plant height), organic fertilizer applications generally yielded more favorable results across most evaluated parameters. The highest grain yield was achieved with cattle manure at a dose of 3000 kg da⁻¹ (CM-5). Cattle manure (CM-5) and chemical fertilizer (CF-3) were both effective in promoting limits the panicle emergence time; however, since cattle manure had a comparable effect to the chemical fertilizer, it was considered a suitable alternative for organic production systems. In the seaweed application, the greatest uppermost internode length was observed at the 40 gda⁻¹ dose. Overall, the results indicated that organic fertilizer forms performed similarly to or better than chemical fertilizers in many traits, with cattle manure showing the most consistent and superior performance among the organic treatments. Based on the findings of this study, cattle manure at a dose of 3000 kg da⁻¹ (CM-5) stands out as the most suitable treatment for oat cultivation under the ecological conditions of Kahramanmaraş. Therefore, organic fertilizers, especially cattle manure, are recommended as effective, environmentally friendly, and sustainable alternatives to chemical fertilizers in oat production.

Author Declarations

Authors' contributions: Concept: S.Ç.S., M.Y., T.K., Design: S.Ç.S., T.K., M.Y., Data collection: S.Ç.S., M.Y., T.K., Analysis: S.Ç.S., M.Y., T.K., Writing: S.Ç.S., M.Y., T.K.

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