

CONJUNCTED FERTILIZATION REGIMES BOOST SEED YIELD AND CHEMICAL COMPOSITION OF SUNFLOWER (*Helianthus annuus* L.)

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ABSTRACT

In the frame of sustainable farming systems to decrease chemical fertilizers use and protect the environment, organic fertilization regimes hold potential as an alternative strategy to supply essential nutrients to crops. A field trial was conducted to sort out the most superior fertilization regime for boosting sunflower production and quality under semi-arid conditions. Treatments included chemical fertilizer (Cf) (80 kg N ha⁻¹ and 80 kg P₂O₅ ha⁻¹), manure from sheep barn manure (MSB) (5161 kg ha⁻¹), manure from cattle barn (MCB) (4878 kg ha⁻¹), liquid manure from cattle barn (LMCB) (27580 kg ha⁻¹) and vermicompost (VCm) (4000 kg ha⁻¹), while a control treatment was kept for comparison purpose. The randomized complete block design (RCBD) with regular arrangement was implied to execute the experiment having three replications. The results exhibited that MSB outperformed rest of fertilization regimes for plant height and leaf number. In contrast, the maximum 1000 seed weight and seed yield were recorded by LMCB. The MCB remained unmatched for protein content, while no significant effect of fertilization regimes was recorded for oil content. Regarding chemical composition, control exhibited the maximum palmitic and stearic acids, while MSB gave the highest arachidic acid.

KEYWORDS:

SPAD, fatty acid, protein content, CM1000 chlorophyll meter

INTRODUCTION

In recent decades, sunflower (*Helianthus annuus* L.) has emerged as one of the most important raw materials for the oil industry globally because it contains a high amount of oil in its seeds (25-50%) [1]. 61.24% of the world oilseed production was met

through sunflower cultivation, while it accounts for over 74% of total vegetable oil production in Turkey [2]. Due to higher adaptability potential, sunflower can grow under varying agro-ecological conditions and soil types, however its yield per unit area needs to be increased so as to meet the demands for vegetable oil consumption [3, 4].

The changing climate scenario has hampered oil seed production while arable lands are continuously on decline owing to urbanization and human settlements [5-8]. For ensuring food and nutritional security of increasing population demands boosting crops productivity on one hand, while halting environmental pollution from agricultural fields has become need of the time [9-11]. In modern intensive farming systems, excessive use of chemical fertilizers (CM) have polluted the environment, and underground water resources leading to undermining human and animal health [12]. However, fact remains that chemical manures (CM) play numerous critical roles in ensuring the food security of increasing populace; however, these have remained ineffective in boosting, restoring and conserving soil organic matter. In addition, suboptimal and inappropriate use of CM over time has damaged soil health and endangered the sustainability of modern farming systems [13]. Furthermore, abundant fossil fuels consumption in preparing CM, leaching of nutrients from agricultural fields, water basins eutrophication, microorganisms and beneficial insects destruction have become serious concerns. Moreover, CM imposed crops sensitivity to a variety of diseases and soil fertility reduction tend to impart serious and irreparable damage to the soundness and productivity of overall agricultural system [14]. On other end of spectrum, organic fertilizers manures have exhibited potential and capability to address most of the challenges and problems posed by excessive use of CM [15, 16]. Moreover, it has been revealed that soil organic matter was inversely correlated with aridity, while its positive correlation was recorded with annual precipitation as well as altitude [18]. To address environmental degradation challenge, organic materials

utilization as a plant nutrients source has attained attention recently. Organic fertilizers (OF) are made up of plant and animal wastes and might be utilized as a plant nutrients source. The OF improve soil aeration and restore soil fertility align with enhancing the water-holding capacity of the soil [14]. The application of liquid cattle manure remained effective in increasing the plant growth and crops yield [15, 16]. Besides crops yield enhancement, the macronutrient uptake and retention but crop plants were significantly multiplied under OF [16] when applied in equal proportions, OF including liquid cattle manure (LCM) remained as effective as CM in meeting plants nitrogen (N) needs as it contained high amount of available nitrogen. In addition to N, liquid cattle manure hold potential to boost soil P and K contents. Furthermore, LCM contained numerous micronutrients which might assist crop plants to attain robust vegetative growth and vigorous reproductive growth [15, 16]. Moreover, LCM increased the solubility of micronutrients in the soil solution which led to significantly higher uptake by crop plants [17]. The OF hold bright perspectives for decreasing soil salinity, hampering mixing of NO₃-N into groundwater, and promoting P availability in the soil solution [18]. Besides, vermicompost proved superior in improving the physical characteristics of the soil such as pore structure, aeration, and water-holding capacity. The impact of vermicompost on seed germination and seedling growth was profound owing to secretion of compounds such as auxin, cytokine, and gibberellin by worms, which trigger plant growth and development [19, 20].

Similarly, solid barn manure contained higher concentration of N, P and K along with many other micronutrients which merit its utilization as plant nutrients source for restoring and conserving soil along with achieving sunflower yield as per varietal potential. However, source and dose optimization of OF for sunflower remains neglected aspects which requisites conducting in-depth field studies in order promote the organic production of sunflower in Turkey. Thus, we hypothesized that optimization of OF source hold potential to boost sunflower seed yield as well chemical composition of the oil owing to better plant nutrition. The purpose of this research was to determine the effect of some organic fertilizer applications (barn manure, liquid barn manure, vermicompost and chemical fertilizer) on the seed yield and some quality elements of sunflower oil under second crop conditions.

MATERIALS AND METHODS

The field experiment was conducted at Research Area of Department of Field Crops, Dicle University, Turkey, in 2019. The experimental site is situated at 37°53' N latitude and 40°16' E longitude at having an altitude of 668 m. The mean temperature

during the crop growing season was 26.18 °C, while the precipitation remained 40.13 mm. The soil samples were taken at 0-30 cm depth before the sowing the crop for determination of chemical and physical properties of the soil. The soil contains 71.6% clay, 1.25% organic matter, 1.63 kg da⁻¹ phosphorus, potassium high level, 13.02% alkaline, 0.01- 0.02% salt and pH 7.73. The seed of cultivated variety of Sanbro (early majority group) was used as planting material. The experiment was comprised of different fertilizers sources including chemical fertilizer (Cf) (80 kg N ha⁻¹ and 80 kg P₂O₅ ha⁻¹), sheep barn manure (MSB) (5161 kg ha⁻¹), manure from cattle barn (MCB) (4878 kg ha⁻¹), liquid manure from cattle barn (LMCB) (27580 kg ha⁻¹) and vermicompost (VCm) (4000 kg ha⁻¹). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The plots were consisted from 4 rows with 6m of length, sowing was done with seed drill in 70x25 cm R x P spaces. Sunflower seeds were sown by hand in the 2th week of June as 4 seeds in a hole. When plants reached a height of 10-15 cm, they were singled out in a way that each hole had one plant. Hoeing was conducted by taking weed density into consideration. Sprinkle-type irrigation was applied 8 times from emergence to the flowering period according to the needs of the crop plants. Sunflower heads were tied with punched plastic bags allowing air ventilation against bird damage during grain filling stage. When sunflowers were at harvest maturity, plants in rows at each plot's sides and plants within 50 cm at top and bottom of each plot were reaped as border effect and the remaining plants in 7 m² area were harvested. Heads were dried out for 3 or 4 days in a shade place after the harvest and they were blended separately. The amount of chlorophyll was measured with the help of a chlorophyll meter (SPAD-502, Minolta and CM 1000) from 10 randomly selected plants from each plot between 11-13 hours when the weather was clear, sunny and cloudless. It took measurements from the leaf in the first node from the top down, which had finished developing so that the plant did not reach the veins of the leaf.

Statistical analysis. Experimental data were subjected to analysis of variance (ANOVA) technique with help of the computer statistical package JMP 10. Significant means were compared using LSD multiple comparison test at 5% significance level.

RESULTS AND DISCUSSION

The data obtained revealed that the effect of different fertilization regimes (Table 1, 2, 3). In terms of plant height, the study found statistically significant differences between the applications at the P ≤ 0.01 level (Table 1). The tallest plants (130.03 cm)

were recorded for MSB, and it was followed by MCB, LCBM gave the minimum plant height (97.26 cm) of sunflower (Table 1). Plant height varies according to variety genetic structure, agricultural practices, and environmental conditions [21]. Previously, it has been reported that irrigation, planting time, plant density and environmental factors played vital roles in increasing plant height. In addition, it has been reported that the difference in plant height was resulted owing to different responses of sunflower to plant nutrition practices [22, 23].

The difference between the applications in terms of the number of leaves was found to be significant at the $p < 0.05$ level. The number of leaves per plant ranged from 12.44 to 16.33, with the highest number of leaves per plant was exhibited by (Table 1).

In the study, the differences between the applications in terms of head diameter (HD) were found to be statistically significant ($p < 0.01$) as it varied between 15.77-20.27 cm (Table 1). The highest HD (20.27 cm) was recorded for LCMB, while the lowest corresponding value was recorded for control treatment (15.77 cm). Head diameter is considered a crucial factor that directly affects the seed yield of sunflower and might be used as a reliable indicator to project yield. Besides genetics, head diameter in sunflower varies depending on many factors such as ecological factors, soil structure and cultural practices especially plant nutrition management. However, [24] stated that it can be highly affected by factors such as head size, especially temperature, soil moisture and fertility, and planting time. In addition, in many studies, it has been reported by many researchers that the head diameter has a positive effect on grain yield, thousand grain weight and oil yield [25, 26, 27].

The mean values of the measured chlorophyll content are presented in Table 1. The difference between cultivars in terms of chlorophyll content values measured in both growth periods of the plants was found to be statistically significant at the $P < 0.05$ level. In our study, the average SPAD 1 values between applications varied between 40.83 and 45.83. The highest SPAD 1 values were determined in Liquid Barn Manure (Cattle), barn manure (cattle) and chemical fertilizer applications (45.30, 45.26 and 45.83, respectively), while the lowest value was determined in vermicompost (40.83). In addition, SPAD 2 values varied between 35.80-42.53, the highest value was determined in chemical fertilizer (42.53) application, and the lowest value was determined in vermicompost (35.80) application. A high chlorophyll content of the leaf is a desirable feature [28]. [29] Fischer (2001) reported that the chlorophyll content of leaves reflects their photosynthetic capacity, [30] reported that there is a high correlation between the SPAD value read on the leaf by the SPAD meter and the chlorophyll content [31] stated that a high value of chlorophyll content in the plant is a desirable trait which significantly contributed to grain yield by boosting photosynthesis capacity. The difference between the chlorophyll values measured with the CM 1000 (1) chlorophyll meter in both periods in the application of different forms of nitrogen was found to be statistically significant. While CM 1000⁻¹ measurement values changed between 237.33-291.33, the highest value was determined in chemical fertilizer (291.33) application. CM 1000⁽²⁾ measurement values varied between 217.66-271.66. The lowest chlorophyll value was determined in vermicompost (217.66) and control (218.60) applications, while the highest value was determined in chemical fertilizer (271.66) applications.

TABLE 1
Plant height (PH), leaf number (LN), head diameter (HD), SPAD 1-2 and CM-1000 1-2 of sunflower under varying fertilization regimes.

Fertilization regimes	PH (cm)	LN	HD (cm)	SPAD (1)	SPAD (2)	CM-1000 (1)	CM-1000 (2)
Control	117.50c	15.77ab	15.77d	43.70ab	37.50b	245.03b	218.60c
Sheep barn manure	130.03a	16.33a	18.29bc	43.93ab	40.60ab	237.33b	219.66c
Chemical fertilizers	112.21c	12.44b	17.72c	45.83a	42.53a	291.33a	271.66a
Cattle barn manure	118.23b	14.77ab	19.33ab	45.26a	39.23ab	263.00b	244.73b
Vermicompost	119.23b	13.88ab	17.11cd	40.83b	35.80b	258.66b	217.66c
Cattle liquid barn manure	97.26d	15.22ab	20.27a	45.30a	40.36ab	254.00b	227.73bc
Significance	**	*	**	*	*	*	**
LSD (5%)	2.09	3.42	1.58	3.39	4.89	27.22	24.94
CV (%)	1	13	5	4.2	6.8	5.7	5.8

*, **, Significance difference at $p \leq 0.05$. $p \leq 0.01$ respectively, LSD: Least significant differences, CV: Coefficient of variation

TABLE 2
Seed yield (SY), 1000 seed weight (TSW), oil content (OC), protein content (PC), oleic acid (OA), linoleic acid (LA), linolenic (LiA) acid of sunflower under varying fertilization regimes.

Fertilization regimes	SY (kg ha ⁻¹)	TSW (g)	OC (%)	PC (%)	OA (%)	LA (%)	LiA (%)
Control	2017.8d	46.03d	42.55	22.75b	33.21c	55.85ab	0.22b
Sheep barn manure	2157.4c	49.03c	43.88	22.83b	34.02b	56.29a	0.28a
Chemical fertilizers	2174.0c	49.96bc	43.25	22.93ab	34.92a	55.59ab	0.13c
Cattle barn manure	2232.0b	50.84b	42.29	23.36a	34.04b	53.26c	0.13c
Vermicompost	2123.0c	48.52c	42.97	23.03ab	34.00b	55.14b	0.14c
Cattle liquid barn manure	2382.5a	52.85a	42.76	22.94ab	34.11b	55.71ab	0.13c
Significance	**	**	ns	*	**	**	**
LSD (5%)	56.0	0.16	1.90	0.44	0.34	1.13	0.02
CV (%)	1.4	2	2.4	1	1	1	7

*, **, Significance difference at $p \leq 0.05$. $p \leq 0.01$ respectively, LSD: Least significant differences, CV: Coefficient of variation

The seed weight is vital yield attribute and might be used as a reliable attribute to forecast seed yield of sunflower. In the study, the differences between 1000 grain weights were found to be significant at the $p < 0.01$ level in terms of applications. It varied between 46.03-52.85 g (Table 2). In the study, the highest thousand seed weight was determined in Liquid Barn Manure (Cattle) (52.85 g) application. The lowest thousand seed weight was obtained in the control (46.03 g) application. It might be inferred that abundant nutrients present in organic manures caused more assimilates translocation towards reproductive parts which maximized the seed weight [34]. For seed yield of sunflower, different fertilization regimes performed statistically differently (Table 2). Average seed yield varied between 2017.8-2382.5 kg ha⁻¹. The highest seed yield (2382.5 kg ha⁻¹) was obtained in the LCMB application, while the lowest yield value was obtained in the control (2017.8 kg ha⁻¹) treatment. In addition to genotype, slow and steady release of nutrients from LCMB might be attributed for better seed yield of sunflower and similar findings have been reported earlier whereby organic manures boosted sunflower yield by supplying adequate macro and micronutrients. It was also inferred that organic manures especially liquid manure from cattle barns contained numerous micro and trace elements which assisted sunflower plants to attain vigorous growth that led to maximum seed yield [32, 33].

In the study, there was no statistical difference between the applications in terms of fat ratio. (Table 2). The oil rate varied between 42.29 and 43.88%. [24] Stated that the chemical composition of sunflower seeds may vary depending on different factors, including growing conditions, temperature, fertilization, irrigation and variety characteristics. The temperature increase during the seed formation period has a reducing effect on the oil rate [35]. Previously, it has been reported that poor plant nutrition management resulted in serious decline of oil content [36]. In addition, it was also concluded that organic manures remained effective in boosting oil content of sunflower as compared to chemical fertilizers [38].

The difference between the applications in terms of protein ratio was found to be significant at the $p < 0.05$ level (Table 2). The protein ratio varied between 22.75-23.36%. In the study, the highest protein ratio was determined in barn manure (cattle) application with 23.36%, and the lowest in control (22.75%) and barn manure (sheep) application (22.83%) [24]. It was revealed that the protein ratio varies depending on the genetic of specific cultivar, while there was no significant effect of cultural practices including fertilization regimes [34].

Fatty acids. There were statistically significant differences between the applications in terms of fatty acids ratio (Tables 2 and 3). Fatty acid composition is an important determinant of oil quality in oilseeds. The composition of fatty acids, triacylglycerols and bioactive compounds of oilseeds can vary significantly depending on variety, location and post-harvest processing technology [39].

Oleic acid ratio varied between 33.21-34.92%. While the highest oleic acid ratio was obtained as chemical fertilizer application (34.92%), the lowest corresponding value (33.21%) was obtained in control. The effect of temperature increase on fatty acids is important in sunflower that has been reported to be influenced by temperature [40]. It has been reported that the oleic acid ratio increases in sunflower by organic manures applied under high temperature [41-43].

It is seen that the effect of nitrogen sources on the linoleic acid ratio is important. While the linoleic acid ratio varied between 53.26-56.29%, the highest value was obtained in barn manure (sheep) application. [24] Reported that the genetic characteristics of genotypes, environmental factors, sowing and harvesting times affect the fatty acid composition, and that low temperature or short photoperiod may increase the linoleic acid ratio at the end of the flowering period and the seed setting period. [44] Reported in their study that while the linoleic acid content varied between 59.02-64.11% in early sowing, the linoleic acid content increased when sowing time was delayed.

TABLE 3
Palmitic acid (PA), stearic acid (SA), arachidic acid (AA), eicosenic acid (EA) and oleic/linoleic (O/L) of sunflower under varying fertilization regimes.

Applications	PA (%)	SA(%)	AA(%)	EA (%)	O/L (%)
Control	6.92a	4.80a	0.33c	0.08bc	0.59d
Barn Manure (Sheep)	5.95c	3.78c	0.42a	0.09ab	0.60cd
Chemical Fertilizer	6.07b	4.18b	0.39b	0.08bc	0.62ab
Barn Manure (Cattle)	5.97bc	4.23b	0.34c	0.07c	0.63a
Vermicompost	5.23d	4.92a	0.38b	0.09ab	0.61bc
Liquid Barn Manure (Cattle)	5.24d	4.99a	0.39b	0.09a	0.61c
Variance	**	**	**	*	**
LSD (5%)	0.10	0.31	0.01	0.01	0.01
CV (%)	1	4	3	0.9	1.2

*, **, Significance difference at $p \leq 0.05$. $p \leq 0.01$ respectively, LSD: Least significant differences, CV: Coefficient of variation

Linolenic acid ratio varied between 0.13-0.28%. The highest linolenic acid ratio was obtained in barn manure (sheep) application (0.28%).

Significant differences were observed between the applications in terms of palmitic acid ratio and the palmitic acid ratio was determined between 5.23-6.92%. [24] reported that the fatty acid contents of oil plants are not constant; It has been reported that the characteristic differences of varieties, environmental factors and temperature, as well as low or high palmitic acid content may be affected by the temperature during the grain formation period.

In terms of stearic acid, the difference between applications was significant and the ratio of stearic acid varied between 3.78-4.99%. The lowest stearic acid ratio was obtained in barn manure (sheep) (3.78%) application, while the highest value was found in control (4.80%), vermicompost (4.92%) and liquid barn manure (cattle) (4.99%) applications. Palmitic and stearic concentrations were the least sensitive to temperature changes, although (at 40/33 °C) changes were also observed [45].

Arachidic acid ratio varied between 0.33-0.42% and fertilization regimes varied significantly among themselves as the lowest arachidic acid ratio was determined in control (0.33%) and barn manure (cattle) (0.34%) application, while the highest corresponding value was obtained from SBM.

Significant differences were determined between the applications in terms of eicosenic acid ratio and varied between 0.07-0.09%. The lowest eicosenic acid ratio was determined in CBM, while the highest value was recorded for LMCB Treatment recorded significant differences pertaining to oleic acid / linoleic acid ratio, while the highest value was exhibited by CBM.

CONCLUSIONS

Our research findings were in line with the postulated hypothesis as sunflower responded differently to integrated fertilization regimes. Sheep barn manure remained superior in terms of plant height

and leaf number. In addition, the maximum 1000 seed weight and seed yield were recorded for liquid manure from cattle barn. The cattle barn manure remained unmatched for protein content, while no significant effect of fertilization regimes was recorded for oil content. It is inferred that liquid manure from cattle barn might be recommended for boosting seed yield of sunflower, while further studies are needed to evaluate the effect of its varying doses on sunflower growth, yield, chemical characteristics of the grain along with soil physico-chemical characteristics.

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