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COHERENT FERTILIZATION REGIMES BOOST PRODUCTIVITY AND NUTRITIONAL QUALITY OF SOYBEAN (*Glycine max*. L. Merrill)

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ABSTRACT

Environmental pollution caused by leaching and gaseous emissions from chemical fertilizers necessitates evluation and optimization of organic sources of plant nutrition for soybean production under changing climate scenario. A field study was executed to test different fertilization regimes including chemical fertilizers (CF) (80 kg N and 80 kg P_2O_5 ha^{-1}), sheep barn manure (SBM) (5161 kg ha^{-1}), cattle barn manure (CBM) (4878 kg ha^{-1}), liquid cattle barn manure (LCBM) (27580 kg ha^{-1}) and vermicompost (VC) (4000 kg ha^{-1}). The yield attributes, grain yield and fatty acid composition of soybean were taken as response variables in this investigation. The experimental design was randomized complete block design with three replications. The results revealed that SBM and CF recorded the tallest plants and first pod height respectively at both R1 and R5 growth stages. In addition, SBM remained superior for recording significantly higher leaf number at R1 and R5 and node number at R5 stage along with maximum pod number and seeds per pod. The maximum 1000 grain weight and grain yield were exhibited by LCBM which was followed by SBM. İn addition, CBM gave the highest protein content while LCBM recorded the maximum oil percentage along with linoleic, mysteric and behenic acid contents. Furthermore, LCBM outperformed other fertilization regimes in terms of palmitoleic, stearic, linolenic and arachidic acids percentages along with oleic: linoleic acid ratio.

KEYWORDS:
Barn manure, Vermicompost, Fatty acid, Grain yield, Oilseed

INTRODUCTION

Soybean (*Glycine max* L. Merill) is increasingly gaining importance as an industrial crop for oil extraction and its haulms are used as protein-rich feed for dairy animals [1]. It is annual plant from the leguminous family and has been declared wonderful plant of the century as its seeds contain 36–40% protein, 18–24% oil, 26% carbohydrates and 18% mineral substances [2]. In comparison to other oilseed crops belonging to Brassica family, soybean oil has been reported to be more suitable for human and owing to the presence of substantial Ca, Fe, Zn minerals and vitamins A, B1, B2, C, D, E, K. Globally, soybean cultivation area was 120.5 m ha with production of 333.6 m tons, while average yield was 2.76 tons per hectare Additionally, over 61% of the world oil seeds production was met from soybean [3]. Like many European countries, Turkey's annual soybean requirement is over 2 million tons while its production was 0.15 million tons attained from an area of over 35 thousand hectares [3].

Soybean yield continues to remain below par in Turkey mainly owing to suboptimal plant nutrition which drastically reduces growth and grain yield. Although, mineral fertilizers serve as instant source of plant nutrients but the loss of nutrient, especially from nitrogenous fertilizers, have posed serious threats to environment and sustainability of farming systems [4, 5]. The intensive farming systems coupled with the use of mineral fertilizers have seriously degraded agricultural soils which give rise to the need for an integrated approach having potential restore, preserve and boost soil health along with maximizing crops yield. The utilization of organic wastes from animal and plant origins hold bright perspectives for boosting soybean yield, conserving the soil and ameliorate environmental pollution [6]. Organic fertilizers increase soil aeration and water holding capacity which enables soybean plants to survive drought spells [7, 8]. Recently, organic vermicompost has gained attention for improving soil physicochemical properties and increasing economic yield of crops. The presence of numerous growths promoting hormones such as auxin, cytokinin and gibberellin in vermicompost secreted by worms play vital role in triggering plants growth and development [9].

Besides vermicompost, other organic manures are also environment friendly along with providing essential nutrients slowly and steadily to plants over a longer period of time which leads to higher productivity on per unit basis. However, organic manures take time in soil to release nutrients which might hamper crop growth and their integrated application with reduced doses of mineral fertilizers can be a way forward to increase organic manures use as a source of plant nutrients [10, 11].

Our research hypothesis was that soybean might respond differently to different sources of organic manures owing to variation in chemical composition and rate of nutrients release in the soil. The prime purpose of this research was to determine the effect of different organic and inorganic fertilizers on yield attributes, seed yield and quality parameters of soybean in the second crop conditions.

MATERIALS AND METHODS

Experimental site details. The field experiment was conducted at Research Area of Department of Field Crops, Dicle University from June to October 2019. The experimental site is situated at 37°53' N latitude and 40°16' E longitude at an altitude of 668 m above sea level.

Soil properties. In order to determine soil physico-chemical properties, soil samples were taken from 0-30 cm depth. The soil samples were collected from four corners and middle of the experimental area which were subsequently mixed to prepare representative samples. The results revealed that soil contained 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.

Meteorological information. Monthly average temperature, total rainfall and average humidity during the experimental period were recorded at the Turkish State Meteorological Station Turkey. During experiment, temperature fluctuated from 18.1 to 31.8 ^{o}C. The average temperature was around 25.3 ^{o}C while average rainfall was 39.13 mm.

Experimental Treatments and Design. Soybean cultivar 'Nova' was used as planting material in this study. The experiment comprised 4 different organic and 1 inorganic fertilizers. Control (no fertilizer), inorganic fertilizer (CF) (80 kg N and 80 kg P_2O_5 ha^{-1}), sheep barn manure (SBM) (5161 kg ha^{-1}), cattle barn manure (CBM) (4878 kg ha^{-1}), liquid cattle barn manure (LCBM) (27580 kg ha^{-1}) and vermicompost (VC) (4000 kg ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The experimental plots were of 6 m length had 4 rows of soybean with 6 m of length, while sowing was done machine as 70x5 cm of spaces. Sprinkle-type irrigation was applied 8 times from emergence to the flowering period according to the needs of the plants.

Investigated traits. Different yield attributes such as plant height, first pod height, stem height, leaf number, node number, handle diameter, pod number, seed number, 1000 seed weight and seed yield were taken as response variables. In addition, quality parameters including protein content, oil content, fatty acid composition and oleic/linoleic rate and saturated-unsaturated fatty acid components were also investigated. Protein content (%) was determined with Kjeldahl method. Oil content (%) was measured with the use of a Soxhlet apparatus including n-hexane (60 °C) as an organic solvent. Seed fatty acid composition was determined by using gas chromatography technique.

In order to perform statistical analyses of recorded data, mean data were subjected to analysis of variance (ANOVA) with JMP 10 statistical software in accordance with randomized complete blocks design (RCBD). Significant means were compared by using least significant difference test at 5% and 1% significance level.

RESULTS AND DISCUSSION

Plant height. Significant differences were determined in soybean plant height at the beginning of bloom (R1) and seed formation (R5) as influenced by fertilization regimes (Table 1). The tallest plants were recorded for SBM, while the lowest plant height was given by control and chemical fertilizer treatments (Table 1). Despite being a leguminous plant, it removes a large amount of N from the soil solution at earlier growth and development stages as nodules take time to become fully functional. The N supplied as organic manure encourages the development of leaves and stems along with triggering numerous physiological processes occurring within plants and thus ultimately influences grain yield and quality. The slow and steady release of nutrients from SBM positively affects plant height and plants attain height as per genetic potential which leads to optimal grain yield of soybean. Contrastingly, plant height was reported to be affected by environmental factors such as daylight and temperature, as well as cultural practices such as planting time, planting density, and irrigation scheduling [12, 13]. Mekki and Ahmed [14] concluded that taller plants were obtained by co-application of mineral and organic fertilizers. In addition; many researchers have stated that the organic and inorganic fertilizer mixture has a greater effect on increasing plant height [15-18]. However, İlker et al. [19] reported that inorganic fertilizers increased plant height compared to organic fertilizers.

TABLE 1
Plant height R1-R5 and first pod height, leaf number, node number as influenced by fertilization regimes in second crop soybean

Applications	PH R1 (cm)	PH R5 (cm)	FPH (cm)	LN R1 (cm)	LN R5 (cm)	NN R1 (cm)	NN R5 (cm)
Control	26.83ab	48.83c	11.56c	26.33c	37.66c	9.66	10.33b
SBM	32.16a	69.16a	13.63b	36.00a	94.33a	10.73	14.00a
CF	25.50b	41.66d	15.50a	32.66ab	65.00b	10.00	10.35b
CBM	25.33b	50.33c	9.16d	29.66bc	100.00a	10.66	14.00a
VC	29.50ab	51.33c	13.16b	32.00ab	70.33b	10.30	12.65a
LCBM	30.50ab	60.50b	13.46b	32.67ab	102.00a	10.10	14.33a
Variance	**	**	**	**	**	Ns	**
Lsd	5.35	5.90	1.43	0.41	1.38	1.96	2.21
CV (%)	10	6	6.2	7	9.4	10.6	10

* Significance difference at $p \leq 0.05$. ** Significance difference at $p \leq 0.01$, LSD: Least significant differences, CV: Coefficient of variation, PH: Plant Height, FPH: First Pod Height, LN: Leaf Number, NN: Node Number, SBM= sheep barn manure, CF= chemical fertilizers, CBM= cattle barn manure, LCBM= liquid cattle barn manure

First pod height. First pod height is an important criterion for machine harvesting in soybean farming as closeness of the pods to the soil surface adversely affects harvesting operation and grain yield. In the study, the highest first pod height (15.50 cm) was obtained from chemical fertilizer application, while the lowest value was recorded for CBM (Table 1). The CF resulted in greater pod height owing to readily availability of nutrients and lower pod height in soybean caused significant yield loss due to inability to harvest the pods that were close to the soil surface [20-23]. However, differences in first pod height could also be investigated with respect to interactive effects of genetic characteristics of the specific variety with fertilization regimes and agronomic management practices like planting time and density and agro-environmental factors especially temperature and rainfall.

Leaf number. The results revealed that number of leaves remained in the range of 26-36 per plant in R1 and 37-102 per plant in R5. The highest number of leaves was obtained for SBM application in the R1 and R5 periods. The slow release of N along with other nutrients from SBM tends to trigger growth and resultantly a greater number of leaves per plant were produced. The higher number of leaves contribute to biosynthesis of assimilates in greater concentration which led to higher grain yield of soybean [24, 25]. In contrast to our findings, Xuewen [26] concluded that nutrients sources had little effect on the average number of leaves per plant.

Node number. The fertilization regimes remained insignificant for R1, significant differences were observed during R5 period (Table 1). While the number of nodes was determined in the range of 9.66-10.73 in R1, the highest number of nodes in R5 was recorded by vermicompost which was statistically at par to SBM and CBM. İn addition to N, other macro and micro-nutrients supplied by organic manures might be attributed to increased number of nods. These findings are in contradiction with those of Iqbal et al. [1], who reported that mineral-organic fertilization regimes had not to effect on plant height and node number in irrigated soybean and also suggested that genetic factor seemed to determine the number of nodes.

Pod number. In soybean, the number of pods is an important yield attribute and contributes significantly. In the study, the highest number of pods was obtained in CBM application, while the lowest values were obtained in the control treatment Devi et al. [27] recommended that co-application of chemical fertilizer, phosphate solubilizing bacteria and vermicompost remained unmatched for enhancing number of pods per plant. In contrast, Uçar [28] reported that vermicompost application did not significantly affect the number of pods However, Kumar et al. [29] stated that vermicompost containing numerous nutrients and mineral increased the number of pods in the plant, while Gül and Arslanoğlu [30] stated that different source of nutrients has non-significant effect on the number of pods per plant of soybean. However, number of pods may vary due to the differences in the genetic structures of the varieties, sowing time (early-late) and local ecological conditions [31].

Seed Number. The seed number is a vital trait that has a positive relationship with grain yield of soybean. In this study, the highest seed number was obtained for CBM which remained statistically at par to LCBM, while chemical fertilizer and control treatments could not perform at par to rest of the treatments (Table 2). A variety of nutrients and minerals provided by cattle barn manure might be attributed for higher number of seeds in soybean; however, difference in the number of soybean seeds was reported to be due to genetic potential of the specific cultivar [32].

TABLE 2
Pod and seed number, 1000 seeds weight and seed yield of soybean as influenced by different fertilization regimes

Applications	PN	SN	TSW (g)	SY (kg ha^{-1})
Control	26.10e	100.28c	97.76d	3045.80de
SBM	34.36c	112.37b	125b	3523.36b
CF	30.66d	97.24c	131.20ab	3412.10bc
CBM	65.20a	209.96a	111.66c	3254.90cd
VC	34.33c	112.27b	99.60d	2987.66e
LCBM	61b	203.39a	133.96a	3871.76a
Variance	**	**	**	**
Lsd	2.37	7.09	7.08	222.32
CV (%)	3.1	2.7	3.3	3.6

* Significance difference at $p \leq 0.05$. ** Significance difference at $p \leq 0.01$, LSD: Least significant differences, CV: Coefficient of variation PN: Pod Number, SN: Seed Number, TSW: 1000 Seed Weight, SY: Seed Yield, SBM= sheep barn manure, CF= chemical fertilizers, CBM= cattle barn manure, LCBM= liquid cattle barn manure

Thousand seeds weight. Seed weight is an important indicator of grain yield and might be used as a reliable parameter to project grain yield of soybean. In contrast to previous trend, the highest 1000 grains weight was recorded by LCBM, while the minimum corresponding value was given by control treatment (Table 2). Previously, it has been established that soybean seed weight depends on factors like genotype, environmental factors and agronomic management (planting density, weeding, irrigation, soil fertility status etc.), however appropriate plant nutrition management was reported to be the single most vital factor [1, 30]. Mandal et al. [15] concluded that combination of chemical fertilizer + 10 t ha^{-1} farm manure remained instrumental in boosting 1000 grains weight of soybean and suggested that this co-application kept on supplying nutrients for a longer period of time which improved vegetative growth and ultimately greater amount of assimilates were partitioned to reproductive parts which led to higher grain weight. Similar findings were also reported by Öztürk et al. [33] who opined that nitrogen sources had varying impact on seed weight of soybean and mineral fertilizers applied in conjunction with organic manures could outperform sole chemical fertilizers in terms of grain weight and grain yield of soybean.

Seed yield (kg ha^{-1}). The grain yield of soybean is the result of yield attributes like plant height, number of pods and seeds per plant, 1000 grain weight etc. As per results of our study, the maximum grain yield was exhibited by LCBM and it was followed by CF which remained statistically at par to SBM. The control treatment recorded the lowest grain yield of soybean (Table 2). It could be inferred that LCBM significantly improved yield attributes which led to higher grain yield of soybean [34]. Coulter et al. [35] stated organic manures had the potential to boost grain yield of soybean by supplying macro and micro nutrients slowly unlikely to mineral fertilizers which resulted in better yield attributes and grain yield. Ozturk et al. [33] also reported similar findings whereby seed yield was significantly affected by organic sources of nitrogen sources while their performance was even more boosted by inoculation of bacteria [36, 37]. Likewise, Küçükyumuk [38] concluded that combined use of vermicompost and mycorrhiza increased grain yield through higher nutrient uptake and greater nutrients use efficiency.

Protein content. Fertilization regimes significantly differenced quality traits of soybean including protein content (Table 3). The protein content varied between 35.34-36.97%, while the highest protein content was obtained from CBM (36.92%) which performed at par to VC (36.97%) and CLBM (37.09%). The control treatment remained inferior to rest of the treatments in terms of protein content of soybean (Table 3). Tremblay et al. [39] stated that the effect of sowing time on protein content was not significant, whereas Muhammad et al. [40] stated that the protein content increased with the delay of sowing time. Öztürk [32] stated that there is a difference in protein content between varieties and this difference is due to genetic structures and environmental factors. While Saini and Chongtham [41] reported that nitrogen fertilizer increased protein content, Öztürk [42] reported that nitrogen source had no effect on protein content.

Oil content (%). Oil content of soybean determines its value owing to extraction of soybean oil for human utilization as cooking oil. In our study, while the oil content varied between 21.91% and 24.13%. The high oil content was exhibited by control treatment (24.13%), while the lowest corresponding value was noted for SBM (2.29%) (Table 3). These findings are in contradiction with those of Öztürk [42] and Fecak et al. [43], who reported that nitrogen sources had significant effect on oil content as chemical fertilizers gave the maximum oil content in comparison to organic manures. However, Güllüoğlu et al. [44] suggested that soybean oil content depends on genetic potential of soybean cultivars and fertilization regimes had non-significant influence on oil content [40, 45, 46]. Furthermore, an increase in N amount was reported to cause significant decrease in oil content of soybean cultivars under varying agro-climatic conditions [47-49].

Fatty acids. Fatty acid composition is an important determinant of oil quality of oilseed crops including soybean. Fertilization regimes had no significant influence on oleic and palmitic acids contents. Chemical fertilizer gave the maximum linoleic acid, while CLBM remained unmatched for behenic and mysteric acids (Table 3). Similarly, CLBM outperformed other fertilization regimes in terms of palmitoleıc, stearic, linolenic and arachidic acids percentages along with oleic and linoleic acid ratio. However, it remained at par to chemical fertilizer for palmitoleic acid content and also performed non-significantly with vermicompost for stearic, linolenic and arachidic acids percentages. All fertilization regimes remained ineffective regarding eicosenoic acid synthesis in soybean grains (Table 4). These findings primarily corroborate with previous reported results by Iqbal et al. [1] and Bachlava et al. [50], whereby integrated fertilization entailing chemical fertilizers and organic manures outperformed solo chemical fertilizers in terms of fatty acids biosynthesis in soybean grains.

TABLE 3
Protein, oil, oleic, linoleic, palmitic, myristic and behenic acid contents of soybean as influenced by fertilization regimes.

Applications	PC (%)	OC (%)	Oleic acid (%)	Linoleic acid	Palmitic acid (%)	Mysteric acid (%)	Behenic acid (%)
Control	35.34c	24.13a	27.01	39.116b	12.75	0.15ab	0.75ab
SBM	35.90b	20.30d	26.97	38.59b	12.56	0.14ab	0.77ab
CF	36.01b	23.85ab	27.28	41.79a	12.75	0.13ab	0.48b
CBM	36.92a	21.91c	26.75	38.17b	12.32	0.14ab	1.08a
VC	36.97a	22.87bc	26.68	37.69b	12.14	0.13b	1.18a
LCBM	37.09a	22.29c	26.99	38.39b	12.29	016a	1.05a
Variance	**	**	Ns	**	Ns	**	**
Lsd	0.31	1.18	0.72	2.67	0.71	0.02	0.48
CV (%)	0.04	2.8	1.4	3.7	3.1	10.2	3.1

* Significance difference at $p \leq 0.05$. ** Significance difference at $p \leq 0.01$, LSD: Least significant differences, CV: Coefficient of variation, PC: Protein Content, OC: Oil Content, SBM= sheep barn manure, CF= chemical fertilizers, CBM= cattle barn manure, LCBM= liquid cattle barn manure

TABLE 4
Palmitoleic, stearic, linolenic, linoleic, arachidic, eicosenoic and oleic/linoleic acid of soybean as influenced by fertilization regimes

Applications	Palmitoleic acid (%)	Stearic acid (%)	Linolenıc acid (%)	Arachidic acid (%)	Eicosenoic acid (%)	O/L Ratio
Control	0.10d	7.91ab	10.89ab	0.99a	0.46	0.68ab
SBM	0.11bcd	7.92ab	11.48a	1.23a	0.55	0.70a
CF	0.13ab	7.02c	10.24b	0.71b	0.45	0.65b
CBM	0.11cd	8.09ab	11.71a	1.07a	0.50	0.70a
VC	0.13bc	8.37a	11.66a	1.10a	0.64	0.70a
LCBM	0.15a	8.45a	11.05ab	1.10a	0.56	0.70a
Variance	**	**	**	**	Ns	**
LSD	0.02	1.24	0.88	0.26	0.24	0.04
Cv	9.4	8.5	4.3	13.9	2.5	3.6

* Significance difference at $p \leq 0.05$. ** Significance difference at $p \leq 0.01$, LSD: Least significant differences, CV: Coefficient of variation, O/L: Oleic/Linoleic, SBM= sheep barn manure, CF= chemical fertilizers, CBM= cattle barn manure, LCBM= liquid cattle barn manure

CONCLUSION

The findings of our investigation proved in line with postulated hypothesis as different fertilization regimes had varying impact on yield attributes, grain yield and fatty acid composition of soybean grains. Sheep barn manure remained superior in terms of plant height and first pod height along with seed and pod number per plant. Cattle liquid barn manure outperformed rest of treatments for 1000 grain weight and grain yield of soybean. The same treatment recorded higher fatty acids such as mysteric, linoleic, mysteric and behenic acids. Thus, cattle liquid barn manure might be recommended as principal source of plant nutrition for soybean production. However, there is need to evaluate other organic manures from plant and animal origin along with optimizing their doses to boost soybean yield and quality on sustainable basis under changing climate.

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