

DETERMINATION OF THE OPTIMUM LEVEL OF FARM YARD MANURE FOR FORAGE AND SEED YIELD OF FODDER BEET (*BETA VULGARIS* L.) IN CENTRAL GONDAR ZONE, ETHIOPIA

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Abstract

A field experiment was conducted to determine the optimum level of farmyard manure (FYM) for forage and seed production of fodder beet (*Beta vulgaris* L.). Sheep manure (FYM) had the highest N and K concentrations with a remarkable cation exchange capacity (CEC). Manure levels 6, 9 and 12 t/ha (T3, T4 and T5) produced higher plant height, root length and diameter, total fresh and dry biomass yield and seed yield of fodder beet. Though manure levels 6, 9 and 12 t/ha (T3, T4 and T5) had statistically the same effect as a result of varied manure level application and their cost implication, since the cost of 1 ton of manure is estimated at 1200 ETB (23.36 USD) in the study area. Considering better biomass and seed production the use of 6 t/ha manure rate (T3) appears to be optimum and economical when the cost of manure and labour cost for manure application is considered.

Introduction

Fodder beet (*Beta vulgaris* L.) is a productive and well-adapted biennial root crop for livestock feed in the highlands of Ethiopia. It needs a long growing season, 5-7 months and grows best in a cool wet climate. It can produce 8 to 12 t/ha DM yield. It is a dry-season feed that could help to overcome feed shortage during critical periods and this, in turn, has a national benefit in having sustainable production throughout the year. It is highly palatable, nutritious and can produce large amount of digestible dry matter per unit area. Because of the high energy content, the roots have potential as an energy supplement to roughage-based diets but roots are low in protein with crude protein values of 6%, whereas the tops are modest in energy level and reasonably high in crude protein compared with the root. The result obtained by Chakwizira *et al.* (2013) with lactating cattle indicated that for cows with an annual milk yield of 3000-3500 kg of milk, 8-10 kg of fodder beet could replace a kilogram of concentrate in the diet. Fresh fodder beet at the rate of 8 kg per kg of concentrate can replace half or three-quarters of the concentrate ration of milking cows with no significant reduction in milk yield, milk fat and protein percentages (Pacheco *et al.* 2020). Considering the high cost of concentrate and its unavailability, 50% replacement of concentrate by fodder beet could be beneficial to the small-scale or state dairy farms (Pacheco *et al.* 2020).

Use of chemical fertilizers to address the declining soil fertility remains minimal due to farmers' low income, which limits their ability to purchase fertilizers. According to Bonilla-Cedrez *et al.* (2021), the high cost of fertilizer, lack of credit, delays in delivery of fertilizer due to poor transport and marketing infrastructure, and lack of knowledge about their proper usage. In this regard, Farm Yard Manure (FYM) can be used as a cheapest source and easily available fertilizer. Farm yard manure, by its organic nature, improves soil physical, chemical and biological properties, and thereby helps in making soils highly productive and sustainable (Dalley *et al.* 2017, Waghorn *et al.* 2019). FYM not only increases the beneficial activities of microorganisms but also reduces nitrogen (N) losses by increasing Cation Exchange Capacity (CEC) of the soil and improves soil structure by adding organic matter, and also minimizes phosphorus (P) and

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Potassium (K) fixation in all types of soil (Abdel-Lateef 2018). So, using FYM helps address soil fertility issues, rising chemical fertilizer prices, and environmental pollution. The current study was, therefore, conducted with the objectives to determine optimum level of farmyard manure (FYM) fertilizer for better forage and seed yields of fodder beet in the study area.

Materials and Methods

The study was carried out at Jibe washa village, Wogera district (latitude 12° 44' 41.8'' N and longitude 37° 35' 53.4'' E) at an elevation of 2913.4 m.a.s.l. The soil texture of the study area was silt loam and pH 5.1 mean monthly temperature of 12.34°C. Based on meteorological data, the total annual rainfall ranges between 945 and 1424 mm, with a mean value of 1184.5 mm.

Composite soil samples from 0-20 cm depth were collected from each plot just before manure application and after the fodder beet seed was harvested. Soil samples before manure application were taken from the center, while after harvest, five samples were taken at each plot for all the treatments in X fashion using a soil auger. 1 kg composite was taken for laboratory analysis. Similarly, before manure application, sheep manure samples were bulked together, homogenized and then 1 kg composite sample was taken for analysis. Soil and sheep manure samples were collected separately, air-dried, ground and passed through a 2 mm sieve, and analyzed for pH, total N, available P, K, and CEC. Soil and manure pH were measured using a pH meter according to the method outlined by Liu *et al.* (2021). Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method as described by FAO (2021a). Available P was extracted with sodium bicarbonate solution at pH 8.5 following the procedure described by FAO (2021b). Available K was determined by extraction with an ammonium acetate solution (Surleva and Angelova 2022). The soil and manure CEC was determined at pH 7 after displacement of the cations by using 1N ammonium acetate; thereafter, the ammonium was estimated following the procedure of Liu *et al.* (2021). Soil texture was determined using the Bouyoucos hydrometer method (Umut and Emre 2020).

Fodder beet variety (KF-31) was taken as test material and required seeds were collected from Debre Birhan Agricultural Research Center (DBARC) and sown on a seed bed and, after 60 days, transplanted in both the 2018/19 and 2019/20 growing seasons. Seeds were sown at 2 cm depth in the nursery. Seedlings were weeded, watered and managed in a proper way under sheds. The seedling shades were taken out 2 weeks prior to transplanting.

Seedlings were transplanted on a well-prepared bed in RCBD with four replications. Five levels of farmyard manure (0, 3, 6, 9 and 12 t/ha) were used in the treatment. The fresh sample of farmyard manure was taken and oven-dried at 65°C for 72 hrs for moisture determination. The farmyard manure was weighed and applied on a dry matter basis after the estimation of moisture content. The farmyard manure was applied in the plot 20 days before seedling transplanting. Plot size was 3.2*2.8 m. Plant spacing was 40cm and 20 cm between rows and plants, respectively. The field was generally kept weed-free during the growth of the fodder beet. Plant height (cm) at harvest, tops fresh yield (t/ha), root fresh yield (t/ha), root length (cm), root diameter (cm), tops dry matter yield (t/ha), root dry matter yield (t/ha), leaf-to-root ratio and seed yield (t/ha) were estimated.

During sampling, each plot was divided into two halves crosswise with an effective plot size of 1.6 x 2.8 m. One half was used for forage sampling and the other half for seed sampling. Forage sampling was done exactly at 6 months of plant growth, while seed harvesting was performed approximately one month after flowering, when the seeds were almost mature and seed yield was determined at 13% moisture content. In each case, sampling was done from the middle three rows, excluding the guard rows. Immediately after the plants were uprooted the harvested fresh tops and root yields were measured using a Salter balance. Individual samples of fodder beet fresh tops and

fresh roots were taken for DM% analysis, which was oven-dried at 65°C for 72 hrs until constant weight was obtained. Plant height was measured by averaging the natural standing height of ten plants per plot. Root length and root diameter were measured by averaging the length and diameter of ten randomly selected plant roots. To determine the leaf-to-root ratio, five plants per plot were taken at random, separated roots and leaves, dried separately in a paper bag and then the ratio was obtained by dividing the percentage of leaf by the percentage of root. In seed yield determination, seed samples were taken from ten randomly selected plants and before measuring seed yield the seed samples were allowed to air-dry until constant weight was obtained.

The data collected were subjected to analysis of variance (ANOVA) using the R statistical software (Team and DC 2019). When the difference was significant among treatments, LSD test was used to locate differences between the treatment means.

Results and Discussion

Table 1 shows the results of chemical properties of sheep manure and soil of the present study. The sheep manure had a pH of 8.76 and the highest percentage of nitrogen (1.5%) and potassium (0.32%), with the highest concentration of phosphorus (36.12 ppm) and a good indication of the cation exchange capacity (25.91 cmol_c/kg). The present result corroborates with Kim *et al.* (2023), who also reported sheep manure chemical content of 1.53% N, 37.45 ppm P and CEC of 26.21 cmol_c/kg, but the chemical content of manure (9.64 pH and 0.47% K) of their study differed from this study. This could be due to the inherent characteristics of the manure used as a result of the feed materials consumed by sheep at different areas.

Table 1. Chemical composition of sheep manure and soil.

Sample	Chemical composition				CEC cmol _c /kg	Particle size (%)		
	pH	N (%)	P (ppm)	K (%)		Clay	Silt	Sand
Sheep manure	8.76	1.50	36.12	0.32	25.91	-	-	-
Soil before planting	5.10	0.23	27.36	0.02	12.13	21.00	59.36	19.64
Soil after planting								
T2	5.60	0.31	29.21	0.09	14.42	20.65	60.12	19.23
T3	6.52	0.38	30.04	0.11	18.05	19.84	61.25	18.91
T4	7.10	0.42	31.18	0.13	17.24	19.77	61.59	18.64
T5	7.22	0.37	32.38	0.14	18.28	19.42	61.91	18.67

CEC: cation exchange capacity, K: potassium, N: nitrogen, P: phosphorus, pH: power of hydrogen, T2, T3, T4, T5: farm yard manure (3,6,9,12 t/ha, respectively).

Table 1 also shows the initial percentage of the physical components of soil used in the study, where the silt gave the highest percentage (59.36%), which was the maximum as compared to the other components. However, the other soil particles (clay and sand) possess commendable textural capacity. This indicates that the silt and sand particles contribute to the well-drained fodder beet plots and the clay soil texture helps to retain moisture, which helps to the growth of fodder beet. The results revealed that the pH of the initial soil was 5.10, indicating that the soil was moderately acidic (Horneck *et al.* 2011). According to the analysis results, the soil was a silt loam in which a high content of total N (0.23%) and available P (27.35 ppm) but lower K (0.02%) were found. The total N content of the initial soil could be rated as medium (Kim *et al.* 2023). Soils with less than 0.07% total N have limited N mineralization potential, while those having greater than 0.15% total N would be expected to mineralize a significant amount of N during the succeeding crop cycle, showing that most of the soils have good potential for N mineralization (Abdel-Lateef 2018). The overall CEC of the soil was about 12.13 cmol_c/kg (Table 1), which is very low (Abay *et al.* 2015,

Abdel-Lateef 2018). The smallest value in the plot was under continuous intensive cultivation. Previous studies indicated that subsequent cultivation led to decline in CEC (Mojiri *et al.* 2012). Soils with low CEC are more likely to develop deficiencies in potassium (K^+) and more susceptible to leaching of these cations.

Table 1 indicates that post-harvest soil chemical properties and CEC were substantially affected by the manure. As the manure level increases from 3 t/ha (T2) to 12 t/ha (T5) post-harvest soil chemical properties also increased due to the fact that all the nutrients added in the form of manure may not be available to the crop during a single cropping season. The results revealed that the pH of the post-harvest soil ranged from 5.60 (T2) to 7.22 (T5), indicating the soils were moderately acidic to neutral, which is considered as suitable for most crop production (Horneck *et al.* 2011). This finding is supported by Abdel-Lateef (2018) that organic manure has a tendency to increase soil pH during the oxidation process. There was a slight increase of total N in post-harvest soils observed due to an increase in manure level from 3 t/ha (T2) to 12 t/ha (T5). These results might be due to the slow release of nutrients in organic manure and high absorption rate of N by fodder beet plants for production; a reduction of N was found in the soil. Similar results were found by Kumar *et al.* (2022), who reported that fodder beet uses high rates of N fertilizer for optimum biomass and seed production. Available P increased with the use of high-level manure when compared to the low-level manure used. This result shows that as the organic manure increased soil pH the availability of P nutrients in soil also increased.

Available K also increased with the increasing of manure from 3 t/ha (T2) to 12 t/ha (T5). This was expected because organic manures are rich in K content (Jon and Crim 2015). CEC was increased as the manure level increased. Abay *et al.* (2015) and Abdel-Lateef (2018) also reported that (FYM) not only increases the beneficial activities of microorganisms but also reduces nitrogen (N) losses by increasing CEC of the soil and improves soil structure by adding organic matter, and also minimizes phosphorus (P) and Potassium (K) fixation in all types of soil. Soil samples just before manure application and after the fodder beet seed was harvested were found to be silt loam; soil texture might not be changed with the use of manure, except with a slight change in some physical components of soil.

Plant height is one of the important agronomic traits that affect the production and productivity of all forage crops. Plant height of fodder beet was significantly ($P < 0.05$) affected by different levels of FYM application at the forage harvesting stage (Table 2). The result indicated that application of a high level of FYM (6, 9 and 12 t/ha) gave a higher plant height (40.07 to 44.32 cm) as compared to the 0 and 3 t/ha manure application. This indicates that application of high-level organic fertilizer has a remarkable contribution on growth and development of fodder beet. According to Majhi *et al.* (2024), plant height of fodder beet can be improved using organic fertilizer. Wubshet *et al.* (2024) also reported that plant height increases with the increase in FYM. Islam *et al.* (2021) observed that plant height and leaf area of wheat significantly increased by high level of organic fertilizer application.

Yield-related parameters such as root length and root diameter were significantly ($P < 0.05$) affected by different levels of manure application (Table 2). Roots were significantly longer (22.88, 22.26 and 22.06 cm) at 6, 9 and 12 t/ha manure application, respectively, than at 0 and 3 t/ha manure levels where no difference among the highest levels of manure application in producing root length. The diameter of roots receiving 6, 9 and 12 t/ha manure was also significantly higher than at 0 or 3 t/ha manure levels. This is because manure is an excellent source of major plant nutrients such as N, P, K and also provides many of the secondary nutrients that plants require in inducing root length and root diameter. In line with the current result, Kumar *et al.* (2022) also reported that root length and diameter in fodder beet ranged from 19.85 to 22.99 cm and 21.51 to 23.70 cm, respectively, when planted at a higher level of FYM. Furthermore,

these results support the studies conducted on fodder beet by Albayrak and Yuksel (2010), who reported increased root diameter and length with an increase in N application in the form of manure. However, the actual nutrient value of manure from a particular operation will differ considerably due to the type of animals, their food ration, manure collection, storage, application procedures, and climate (Lim *et al.* 2023).

Fresh yield parameters such as fresh leaf and root yield were significantly ($P < 0.05$) affected by manure application (Table 2). Both leaf and root fresh yield increased over the entire range of manure rates used in this experiment. The higher leaf and root fresh yield was obtained from high-level (6, 9 and 12 t/ha) manure application; however, there was no significant ($P > 0.05$) difference observed between high manure levels (6, 9 and 12 t/ha) in producing leaf and root fresh yield. This is due to the fact that high manure levels, with their highest N concentration, can play a remarkable contribution in enhancing plant growth, chlorophyll formation and photosynthesis that ultimately improves both the leaf and root fresh yield. In accordance with the current results of Tiwari and Prasad (2022), who reported that increased leaf and fresh root yield is caused by high manure levels, where N plays a vital role in enhancing growth, chlorophyll formation, the photosynthesis process, and other variables contributing to yield improvement.

Both tops and root dry matter content of fodder beet under different levels of manure application were presented in Table 2. The result showed non-significant ($P > 0.05$) difference among the rate of manure application in producing tops and root dry matter content. The mean value of dry matter percentage of both tops and root was 27.53 and 6.38%, respectively. In contrast to the current result, Mustafa (2007) and Abdel-Lateef (2018) on fodder beet observed a significant difference in the tops and root dry matter content that could be due to different levels of manure application.

Table 2. Mean combined (2019 and 2020) fresh biomass yield and yield components of beet at different farmyard manure levels.

Treatment	PH (cm)	RL (cm)	RD (cm)	TFY (t/ha)	TDMP	RFY (t/ha)	RDMP
FYM (0 t/ha)	35.00 ^c	18.60 ^b	18.62 ^c	28.83 ^c	26.40	22.63 ^b	5.66
FYM (3 t/ha)	37.85 ^{bc}	19.35 ^b	20.50 ^{bc}	33.95 ^{bc}	29.28	30.91 ^b	6.04
FYM (6 t/ha)	44.02 ^a	22.88 ^a	23.97 ^a	44.27 ^a	26.66	44.72 ^a	6.54
FYM (9 t/ha)	44.32 ^a	22.26 ^a	23.35 ^a	42.19 ^a	28.75	46.28 ^a	6.70
FYM (12 t/ha)	40.07 ^{ab}	22.06 ^a	22.67 ^{ab}	39.40 ^{ab}	26.54	40.97 ^a	6.94
Mean	40.25	21.03	21.82	37.73	27.53	37.10	6.38
CV (%)	10.45	9.58	9.85	15.36	15.66	13.19	22.73
LSD (0.05)	4.28	2.05	2.19	5.90	ns	8.76	ns

a, b, c means are significantly different at $p < 0.05$, ns: non-significant at $p > 0.05$, CV: coefficient of variation, FYM: farm yard manure, LSD: least significant difference, PH: plant height, RD: root diameter, RDMP: root dry matter percentage, RFY: root fresh yield, RL: root length, TDMP: tops dry matter percentage and TFY: tops fresh yield.

The dry biomass yield of any forage crop varies from place to place due to soil fertility status, climatic conditions and agronomic management practices. Leaf dry matter (DM) yield of fodder beet was significantly ($P < 0.05$) affected by different manure rate applications in Wogera district (Table 3). The result showed that the higher leaf DM yields (10.42 to 12.13 t/ha) were obtained from 6 to 12 t/ha farmyard manure applied. The control (0 t/ha) and 3 t/ha manure applied gave the lower 7.72 and 9.89 t/ha leaf DM yield. This is due to the fact that use of organic nutrient sources at a higher level exhibits multiple effects and synchronizes nutrient release and absorption by the plants. According to Bokhtiar and Sakurai (2005) and Yilmaz (2024), application of high levels (6 to 9 t/ha) of organic manure has been reported to increase absorption of N, P and K in sugarcane

leaf tissue, compared to chemical fertilizer. Majhi *et al.* (2024) also obtained a significant increase in leaf dry matter yields when high level (10 t/ha) organic fertilizer was applied compared with control (0 t/ha) and lower level (4 t/ha) manure application.

Root DM yield of fodder beet also responded differently ($P < 0.05$) for the different manure levels (Table 3). Application of 3 to 12 t/ha farmyard manure produced the highest root DM yield (2.50 to 3.12 t/ha), while the lowest (1.26 t/ha) root DM yield was obtained from the control treatment. Application of 9 t/ha farmyard manure produced 59.61% root DM yield over the control treatment. The high yields observed under different levels of manure application may be as a result of its ability to improve soil biological and physical properties, which increase soil water retention and enhance nutrient uptake (Yılmaz 2024). Effects of manure on soil physical properties include increased infiltration and water-holding capacity (Yılmaz 2024) and reduced compaction and soil erosion (Wubshet *et al.* 2024). However, the actual nutrient value of manure from a particular operation will differ considerably due to the type of animals, their feed ration, manure collection, storage, application procedures, and climate that will be considered during application (Yılmaz 2024).

The response of total (leaf and root) DM yield of fodder beet was also affected by different manure rates. The effects of manure levels were significantly ($P < 0.05$) different for total DM yield of fodder beet (Table 3). The higher total DM yield (13.26 to 15.25 t/ha) was obtained from application of 6 to 12 t/ha farmyard manure, while the control treatment recorded the lowest 8.98 t/ha total DM yield. Total DM yield of fodder beet was significantly increased through application of high-level FYM, which improves the overall soil conditions. The present finding indicated that use of organic sources of fertilizer improves soil physical conditions, soil microbial biomass and dehydrogenase activity (Yılmaz 2024).

Table 3. Mean combined (2019 and 2020) dry biomass and seed yield of beet at different farmyard manure levels.

Treatment	TDMY (t/ha)	RDMY (t/ha)	TDMFY(t/ha)	LTRR	SY(t/ha)
FYM (0 t/ha)	7.72 ^c	1.26 ^b	8.98 ^c	2.30	0.21 ^c
FYM (3 t/ha)	9.89 ^{bc}	2.50 ^a	12.39 ^{bc}	2.55	0.44 ^b
FYM (6 t/ha)	11.78 ^{ab}	2.89 ^a	14.67 ^a	1.80	0.55 ^a
FYM (9 t/ha)	12.13 ^a	3.12 ^a	15.25 ^a	2.03	0.57 ^a
FYM (12 t/ha)	10.42 ^{ab}	2.84 ^a	13.26 ^{ab}	2.23	0.56 ^a
Mean	10.39	2.52	12.91	2.18	0.46
CV (%)	19.85	15.17	17.51	19.50	6.26
LSD (0.05)	2.10	1.16	2.41	ns	0.21

a,b,c are significantly different at $*=p < 0.05$, ns: non-significant at $P > 0.05$, LTRR: leaf-to-root ratio, RDMY: root dry matter yield, SY: seed yield, TDMFY: total dry matter forage yield and TDMY: tops dry matter yield.

There were no significant ($P > 0.05$) differences detected among the farmyard manure rates in affecting the leaf-to-stem ratio of fodder beet, as shown in Table 3. The mean leaf-to-stem ratio was 2.18, which agrees with the finding of Albayrak and Yuksel (2010), who reported leaf-to-stem ratios that range from 1.98 to 2.61 for fodder beet (*Beta vulgaris* var. *crassa* Mansf.) planted at 4 to 12 t/ha farmyard manure rates in the Mediterranean region of Turkey. Wubshet *et al.* (2024) also reported a leaf-to-stem ratio that ranged from 1.74 to 2.63 in fodder beet (*Beta vulgaris* L.) cultivars.

Seed yield is the outcome of the collective contribution of various yield components, which is affected by different growing conditions and crop management practices. Seed yield of fodder beet is also significantly ($P < 0.05$) affected by different manure rates (Table 3). The result showed that the seed yield of fodder beet ranges from 0.21 to 0.57 t/ha. The increase in seed yield continued up to the highest level of 12 t/ha. Thus, the higher seed yield was attained at the higher (6 to 12 t/ha)

farmyard manure application. The result indicated that application of 9 t/ha manure gave the highest (0.57 t/ha) seed yield, followed by application of manure at a rate of 12 t/ha which produced 0.56 t/ha seed yield. On the other hand, the lowest seed yield (0.21 t/ha) was obtained from the control treatment (zero manure application). The increased seed yields observed in the high-level FYM treatments over the control and minimal manure level (3 t/ha) could be as partly due to a more favorable moisture regime in the root zone and partly due to more efficient utilization of nutrients released from decomposition of the added FYM (Abdel-Lateef 2018). This is also most likely because optimum manure applications not only improve soil physical properties but also enhance microbial activities and provide a stable supply of both macro- and micro-nutrients that favor better fodder beet seed production (Jilani *et al.* 2007, Abdel-Lateef 2018).

The chemical analysis results revealed that sheep manure had higher nitrogen and potassium concentrations, with a remarkable cation exchange capacity (CEC) that helps in improving soil biological and physical properties in producing fodder beet forage and seed yield. Among the manure rates used, 6, 9 and 12 t/ha (T3, T4 and T5) in providing desired nutrients and produced relatively higher total (leaf and tuber) dry biomass and seed yield of fodder beet. Even though T3, T4 and T5 (6, 9 and 12 t/ha) have statistically the same effect on total biomass (both tops and root) and seed production as a result of varied manure rate application, they have their own cost implications since the cost of 1 ton of manure is expected at 1,200.00 ETB in the area. Therefore, based on the study results, use of 6 t/ha manure rate (T3) appears to be optimum and economical when the cost of manure and labour cost for manure application were considered. However, seed quality tests and chemical analyses on both fodder beet tops and roots should be done further to verify this research finding in determining the optimum manure rate.

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