Agronomic and Economic Evaluation of Mineral Nitrogen Fertilizer and Farm Yard Manure on Production of Sesame (*Sesamum indicum* L.) in Southeast Ethiopia

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Received: 27 May 2024 *Accepted: 2 July 2024*

Abstract

Sesame is an important oil and cash crop produced in Ethiopia. However, its productivity is low due to inappropriate use of fertilizers. Therefore, a field experiment was conducted at Gode Polytechnic College demonstration site in 2022 cropping season to assess the effect of nitrogen (N) and farm yard manure (FYM) fertilizers on productivity of sesame. The experiment consisted of three levels of FYM (0, 5 and 10 t ha^{-1}) and four levels of N (0, 46, 69 and 92 kg N ha^{-1}). The experiment was laid out in RCBD in a factorial arrangement with three replications. The analysis showed that FYM and N significantly increased plant height, primary branches, capsules $plant^{-1}$ and number of seed $capsule^{-1}$. Moreover, the interaction of N and FYM significantly affected days to flowering and maturity, 1000-seed weight, seed yield, biomass yield, and harvest index. Increasing the rate of FYM and N prolonged the days to flowering and maturity. The maximum 1000-seed weight (4.4) was recorded when 10 t FYM combined with 46 kg N ha^{-1}. Moreover, combination of 10 t FYM ha^{-1} with 46 kg N ha^{-1} resulted in maximum seed yield (1.84t ha^{-1}). Application of 10 t FYM ha^{-1} + 46 kg N ha^{-1} with net benefit (ETB 83,290.00 ha^{-1}) and marginal rate of return (410.04%) outperformed to ensure sustainable production. It could, thus, be concluded that application of 10 t FYM ha^{-1} + 46 kg N ha^{-1} is recommended for sustainable sesame production in study area.

Keywords: Economic benefit, farm yard manure, nitrogen, seed yield, sesame

Introduction

Sesame (*Sesamum indicum* L.) is an important oil crop in the world with high nutritive value (Weiss, 2000). The seeds are rich source of edible oil, protein, carbohydrate, vitamins, lignans, and lipids (Were et al., 2006). The oil is rich in polyunsaturated fat and

contains low cholesterol, and the protein contains essential amino acids such as methionine and tryptophan (Ogundare et al., 2015).

Due to its high demand in the world, production of sesame is increasing (Langham and Wiemers, 2002). A number of countries produce sesame; Ethiopia is the seventh largest producer in the world (FAOSTAT, 2017). The major sesame producing regional states in Ethiopia are Tigray, Amhara, Oromia and Somali. However, due to various limitations sesame yield per unit is very low. There is a wide gap between the national average yield of sesame under rain-fed conditions (400-900 kg ha^{-1}) and under irrigated conditions (1,000-1,800 kg ha^{-1}) (EARO, 2004). Lack of harvesting and threshing machines, seed of improved varieties, and inappropriate use of pesticides by the producers are some of the constraints in sesame production (Tsehay, 2006). However, the main cause of the low productivity of sesame in Somali Regional State, Ethiopia is the inappropriate utilization of fertilizers (Mekonnen et al., 2016) and decline in soil fertility (Nwite et al., 2013) which is related to inherent low soil fertility or depletion through cultivation. The farmers in Somali regional state continuously cultivate with little or without application of the required nutrient to their farms. Thus, most of the arable lands are low in organic carbon and essential nutrients. This resulted in unbalanced soil nutrient composition that in turn led to a reduction in crop yield (Tonfack et al., 2009).

The low fertilizers application of the farmers to their farms was due to lack of awareness and /or they could not afford mineral fertilizers. In Ethiopia, mineral fertilizers such as urea-N are not affordable for poor smallholder farmers (Zerssa et al., 2021), their cost are increasing alarmingly. Studies showed that the price of the fertilizers increased by 170% in between 2020 to 2022 (MoA, 2022). This situation made the poor farmers apply mineral fertilizers below the recommended rate (Endale, 2010). Due to the application the lower rate of fertilizer and other agronomic factors the grain yield are lower as compared with the yields obtained from research stations (Zersa et al., 2021).

Growth, grain yield, seed quality of sesame is affected by fertilizer application either in mineral or organic form (Haruna, 2011). In sub-Saharan Africa (SSA) over 80% of the soils are nitrogen (N) deficient (Vanlauwe et al., 2015). As compared to the other nutrients, nitrogen contributes up to 50% to determine crop yield (Babajide and Oyeleke, 2014). Nitrogen is one of the nutrients that affect growth and yield of sesame. Nitrogen increase plant height, number of capsules per plant, and yield of sesame (Shehu et al., 2010). On contrary, increasing N application beyond the requirement decrease the seed quality such as seed oil content. Therefore, optimum N application is recommended to sesame production.

The soil type, climatic condition and the farming practices are the main factors to determine the rate of nitrogen fertilizer to be applied in specific area (Balasubramanian et al., 2004). Application of 100 kg DAP $ha^{-1}$and 50 kg urea ha^{-1}, which is total N amount of 41kg N ha^{-1}, gave the higher sesame grain yield in Humera, Ethiopia (HUARC, 2012). Barsan variety gave 2.08 t ha^{-1} grain yield using 46 kg N ha^{-1} in Gode under irrigation (Mekonnen et al., 2016).

Application of organic materials are important because they are source of organic carbon and essential nutrients which improves the fertility and physical properties of the soil (Murphy 2015) such as soil aeration, soil density which improves water holding capacity of soil for seed germination and root development (Zia et al., 1998). Organic manures are also preferred

by poor farmers because they are easily available and affordable than chemical fertilizers (Alam et al., 2007). The communities in Somali Regional State are pastoralists and agro-pastoralists, thus there is abundance of FYM resource in the area. However, these resources are not being utilized properly by the community as fertilizer.

Application of organic manure alone will not satisfy the nutrient requirement of the crop. However, combined application of organic manure and mineral fertilizers increase the availability of nutrients (Iren et al., 2014). It implies the combined effect of organic and inorganic fertilizer increase productivity of crop and improves soil quality (Iren et al., 2014). Combined application of mineral N fertilizer and organic manure such as farm yard manure gave higher grain yield of sesame (Sahu et al., 2017). Thus, there is a need to investigate integrated effect of nitrogen fertilizer and organic fertilizer (FYM) on sesame production. Therefore, this study was initiated to investigate the effect of nitrogen fertilizer and farmyard manure on growth and yields of sesame.

Material and Methods

Description of the study area

The field experiment was conducted during 2022 cropping season under irrigation at Gode, Somali Regional State of Ethiopia, which is located at a distance of 1225 km south east of Addis Ababa, and about 580 km south of Jigjiga, the capital city of Somali Regional State. The experimental site is situated at the latitude of $5^0$57'N, longitude of 43°27'E and altitude of 320 meter above sea level. The annual average maximum and minimum temperatures are 35 and 23.6^{0}C, respectively. The mean annual rainfall of the area ranges from 150 to 340 mm which is not sufficient for rain-fed production (SoRSMA, 2013). The study area is characterized by high temperature, erratic rainfall, vast area of plain suitable for large scale irrigated agriculture and livestock (Gebremariam, 2005). The climate is characterized as arid agro-ecology. Rainfall pattern is characterized by main rainy season (*Gu*) that extends from April to June and the short rainy season (*Deyr*) from October to December. The farmers in the study area are mainly engaged in livestock production; but, they also produce fruits (papaya, mango, and banana), vegetables (tomato, onion and pepper), oil crop (sesame) and cereals (maize and sorghum) under irrigation, using the Wabe shebelle river.

Description of experimental materials

The sesame variety Barsan/ACC-00016 (1) was used as a test crop for its higher yield, locally adapted, and preferred by farmers in the area. Barsan variety was released in 2010 by Gode Pastoral and Agro Pastoral Research Center (GoPARC/SoRPARI) (EIAR, 2011). It is dominantly used in the area. It has brown seed, flowering of 50-60 days, and maturity of 80-90 days. Urea (CO ($[NH_2]_2$) (46% N) was used as a sources of nitrogen fertilizer (N). Farmyard manure (FYM) was used as a source of organic fertilizer which is abundantly available locally. The collected FYM had organic carbon content of 5.87% and total nitrogen 1.49%.

Treatments and experimental design

In this study, a factorial combination of three levels of FYM (0, 5, and 10 t ha^{-1}) and four levels of N (0, 46, 69, and 92 kg N ha^{-1}) were used. A randomized complete block design (RCBD) was employed and the treamtents were replicated thrice. Thus, there were total of 3x4=12 treatment combinations and 12 x 3=36 plots.

Experimental procedure and field management

The land was ploughed by a tractor to a depth of 25–30 cm. After layout as per the specification, each plot was leveled and ridged manually. The treatments were assigned randomly to each plot within block. Each gross plot had an area of 2.4 m x 2.0 m (4.8 m^2). A distance of 1 m was left between plots and 1.5 m between blocks. There were 6 rows per plot spaced 40 cm each and inter plant spacing within the rows was 10 cm. The outer most one row on both sides of each plots and two plants from each end of rows were considered as border and were not used for data collection to avoid edge effects. Thus, the net plot size was 1.6 m x 1.6 m (2.56 m^2).

The seeds were sown by drilling in furrows at a depth of about 2.5cm to ensure adequate emergence and were thinned one week after emergence to maintain the recommended spacing of 10 cm intra row spacing when the seedlings attained about 15 cm height. Based on the treatments, well decomposed farmyard manure was applied to the experimental plots 3 weeks before sowing. Half of nitrogen as a form of urea was applied at sowing and the remaining nitrogen was top dressed at pre flowering stage of the crop. Based on the recommendation for sesame, all other agronomic practices were perfomred uniformly for each experimental plot (EARO, 2004). Harvesting was done at physiological maturity when leaves and stems tended to change from green to yellow color and the leaves began to fall from the plants and the bottom capsule started to open.

Soil sampling and analysis

Before planting a composite soil sample at a depth of 0-20cm, representing each plot was taken for determining the physiochemical parameters of the soil of the experimental site. Soil texture, soil pH, organic carbon, total N, available P were taken. To determine nutrient content of farmyard manure representative sample was taken by combining all manure samples on concrete pad mixing thoroughly. The well mixed manure sample was identified by quartering method to get representative sample. Representative samples were grounded to pass through a 0.2 mm sieve for analysis, and analyzed to determine organic carbon, and total N.

Data collection

Starting from date of sowing, days to flower initiation were taken when 50% of the plant population on the net plot area started to bear flower whereas number of days to physiological maturity was recorded when 90% of the plant population in net plot started to turn their leaves yellow, the leaves began to fall from the plants, ¾ capsules on the capsule zone had turned from milky white to an off-white color and lower most capsules started to open (Terefe et al., 2012). Phenological stages were determined by visual observation.

From five randomly taken plants in each net plot area, the height of the main stem was measured from the ground surface to the tip of the apex at the time of physiological maturity. Number of primary branches $plant^{-1}$ was also counted from five randomly taken plants at physiological maturity.

Yield and yield related traits

At physiological maturity number of capsules $plant^{-1}$ was counted from five randomly taken plants. To determine the number of seeds $capsule^{-1}$, the average seeds of three capsules (lower, medium and upper position on the plant) from each of five plants were counted. Thousand seed weight (g) was determined from the count of 1000 seeds after sun drying by

using sensitive balance. The aboveground dry biomass yield was recorded from net plot area by weighing with spring balance and converted into tons (t) ha^{-1}. Seed yield from each net plot area was recorded and converted into tons (t) ha^{-1}. Harvest index was determined by dividing the grain yield with total biomass.

Economic analysis

Partial budget analysis is a method of organizing experimental data about the cost benefit of some changes (CIMMYT, 1988). To reflect the difference between the experimental yield and the yield the farmers could obtain, the actual yield produced under different treatments was reduced downward by 10% (CIMMYT, 1988). To show the net benefit (NB), the total variable cost was subtracted from the gross benefit. To select potentially profitable treatments, the dominance analysis procedure was applied as described in CIMMYT (1988). The marginal rate of return (MRR) was computed as changes in NB divided by changes in cost. A dominance analysis was done by listing the treatments in order of increasing total variable costs. Any treatment that has net benefits that are less than or equal to those of a treatment with lower costs that vary is dominated (D). The cost was calculated for FYM and urea fertilizer which was ETB 200 and 7000 for each 100 kg, respectively. The application cost of FYM ETB 10,000 birr per a truck (with capacity of carrying 10t) of FYM regardless of the amount to cover one hectare of land. The transportation cost to the field was ETB 100 per 100 kg FYM and ETB 500 per 100 kg urea. The local market price of sesame seed at the time of harvest was ETB 8000 per 100 kg.

Statistical data analysis

The data collected was subjected to the analysis of variance (ANOVA) appropriate to the design using SAS Software. The mean separation was performed using LSD at 0.05 level of probability.

Results and Discussion

Physico-chemical properties of the experimental site

The experiment was conducted from October to December, 2022 cropping season under irrigation condition. The experimental site soil analytical results indicated that the soil pH is 7.95 showing moderately alkaline nature of soil (Hazalton and Murphy, 2007). The crop thrives best in soil pH ranging from 5.5 to 8, it implies soil pH of the experimental site was suitable for sesame production. The result of the soil analysis also shows that the soil of the research area can be classified as sandy clay loam that contain total N of 0.03% which falls in the very low range (< 0.05), 5.01 ppm available phosphorus also in the low range (5-10 ppm) and 0.8 % organic carbon which is in the low range (0.6-1.0%) (Hazelton and Murphy, 2007). It indicates that the soil in the study area is low in total N, available P, and organic carbon. Therefore, application of nitrogen fertilizer and farm yard manure the study area is crucial to increase the level of N and C in soil, respectively.

Crop phenology

The interaction effect of farmyard manure and nitrogen significantly ($P < 0.05$) and ($P < 0.01$) influenced days to 50% flowering and days to 90% physiological maturity of sesame, respectively (Table 1). Plants grown under the treatment combination of 0 kg N ha^{-1} and 0 t FYM ha^{-1} flowered earlier (29.66 days) than the rest of the treatments. However, the maximum days to 50% flowering (46.66 days) was recorded from plots that were treated with

combination of 92 kg N ha^{-1} and 10 t FYM ha^{-1}. The results indicated a difference of about 17 days between the highest and the lowest number of days to flowering. The increment of days to 50% flower initiation with the increasing application rates of N might be due to the positive effect of N that may have stimulated growth and prolonged vegetative growth period, thus delaying the reproductive phase of plant (Khan et al., 2009). Days to maturity were prolonged in response to increased levels of FYM (farmyard manure) and nitrogen. Plants grown under the treatment combination of nil-nil nitrogen and FYM application matured earlier (83 days) than the rest. However, the most prolonged maturity time (105 days) was recorded from plots that were treated with 92 kg N and 10 t FYM ha^{-1}, which increased maturity time by about 27% as compared to 0kg N and 0t FYM ha^{-1}.

Table 1. *Interaction effect of farmyard manure and nitrogen on days to 50% flowering and days to 90% physiological maturity of sesame in 2022 cropping season*

FYM (t ha^{-1})	N (kg ha^{-1})	Days to 50% flowering	Days to 90% physiological maturity
0	0	29.66^{h}	83.00^{g}
	46	32.66^{g}	85.00^{fg}
	69	33.00^{fg}	85.33^{f}
	92	34.00^{g}	85.66^{ef}
5	0	34.33^{fg}	85.66^{ef}
	46	36.33^{e}	87.66^{de}
	69	37.33^{de}	87.66^{ed}
	92	38.66^{d}	89.33^{bc}
10	0	38.66^{d}	90.33^{bc}
	46	42.33^{c}	90.66^{bc}
	69	44.00^{b}	91.66^{b}
	92	46.66^{a}	105.00^{a}
LSD $_{(0.05)}$		1.54	2.18
CV (%)		2.45	1.45

Means in columns sharing the same letter(s) are not significantly different at 5% level of significance; LSD=Least Significant Difference; CV= Coefficient of Variation

Growth and yield components

The main effect of the farm yard manure and nitrogen was significant ($P < 0.01$) on the plant height and number of primary branches produced per plant (Table 2). The increase in plant height with increased farmyard manure levels would be attributed to favourable effect of farmyard manure in better availability of N and the enhancing effect of N on cell division and elongation then on vegetative growth.

Enhanced vegetative growth of sesame under the influence of nitrogen application was also observed by Sisay (2014). In case of nitrogen effect, the shortest plants (98.50 cm) were observed for plants grown at nil nitrogen (control) application, while the longest (121.44 cm) plants were observed from application of 92 kg N ha^{-1}.

Increasing the rate of manure supply significantly increased the number of primary branches produced per plant. This result indicated that manure application promotes

vegetative growth and is in line with that of Girma (2015) who reported that application of farmyard manure significantly outperformed the control treatment in terms of number of branches per plant of sesame. When the rate of nitrogen was increased from 0 to 92 kg N ha^{-1}, the number of primary branches per plant increased significantly by about 42.16%.

The two fertilizers had significant ($P < 0.01$) main effects on the number of capsules produced per plant and seed per capsule (Table 2). The number of capsules per plant increased significantly with the increase in FYM rates. This is may be attributed to the positive effect of manure in supplying plant nutrients to the soil and its ability to improve the soil physico-chemical properties which enhances crop growth and development.

When the rate of nitrogen was increased from 0 to 46 kg N ha^{-1}, the number of capsule per plant increased significantly. However, this parameter reduced when the rate of nitrogen was increased above 46 kg N ha^{-1}. Application of 46 kg N ha^{-1} had resulted in about 29.39% higher capsules per plant over control treatment. This result is in line with Sisay (2014) who reported significant response of Barsan variety to number of capsules obtained up to 46 kg N ha^{-1}. Similarly, increasing the level of FYM increased the seed per capsule.

The highest number of seeds (64.22) per capsule was obtained with the application of 10 t FYM ha^{-1} which was statistically in parity with the application of 5 t FYM ha^{-1}. This indicated that farm yard manure supply had the most profound effect on increasing number of seeds per capsule. In response to increasing the rate of nitrogen number of seed per capsule increased. The seeds per capsule were higher with application of N, which may be attributed to more number of leaves and high nitrogen use efficiency and more interception of sun light and at the result more photo assimilates go to reproductive parts of the plant which is seed of sesame (Muhammad *et al.,* 2014).

Table 2. *Effect of farmyard manure (FYM) and nitrogen on plant height, number of primary branches per plant, capsule per plant and seed per capsule of sesame in 2022 cropping season*

Treatment	Plant height (cm)	Branches $plant^{-1}$	Capsule $plant^{-1}$	Seed $capsule^{-1}$
FYM rate (t ha^{-1})				
0	97.98^{b}	2.92^{c}	75.48^{c}	59.64^{b}
5	104.51^{b}	4.20^{b}	96.73^{b}	62.55^{a}
10	127.24^{a}	4.91^{a}	106.78^{a}	64.22^{a}
LSD $_{(0.05)}$	6.59	0.52	7.15	2.43
Nitrogen (kg N ha^{-1})				
0	98.50^{c}	3.32^{c}	74.15^{c}	58.68^{c}
46	109.04^{b}	3.72^{bc}	95.95^{b}	61.88^{b}
69	110.66^{b}	4.30^{ab}	95.48^{b}	61.88^{b}
92	121.44^{a}	4.72^{a}	106.40^{a}	66.10^{a}
LSD $_{(0.05)}$	7.61	0.60	8.26	2.81
CV (%)	7.1	15.5	9.1	4.7

Means in columns sharing the same letter(s) are not significantly different at 5% level of significance; LSD=Least Significant Difference; CV= Coefficient of Variation

The analysis of variance revealed that interaction effect of farmyard manure and nitrogen had significant ($P < 0.01$) effect on thousand seed weight (g) (Table 3). Plants grown under the treatment combination of 0 t FYM ha^{-1} and 0 kg N ha^{-1} produced the lowest thousand seed weight (1.86 g) (Table 3). However, the maximum thousand seed weight (4.40 g) was recorded when 10 t FYM ha^{-1} was combined with 46 kg N ha^{-1}. In response to increasing the rate of nitrogen from 0 to 46 kg N ha^{-1}, the 1000-seed weight was increased significantly. However, when the rate of nitrogen was further increased to 92 kg N ha^{-1}, the 1000 seed weight though was decreased but it was not significant (Table 3). This result might be attributed to the positive role of N in the physiology of the plant in cell elongation and encouraging aboveground vegetative growth, photosynthesis and ultimate partitioning of photosynthate to the seed.

Yield and harvest index

It is clearly evident from Table 3 the interaction effect of farmyard manure and nitrogen had significant influence on seed yield of the sesame crop. The results indicated that combined application of FYM at 10 t ha^{-1} with 46 kg N ha^{-1} gave maximum seed yield (1.84 t) which was statistically in parity with the combined use of FYM at 10 t ha^{-1} with 69 kg N ha^{-1}. It was also observed that the seed yield increased with the increase in FYM application up to 46 kg ha^{-1} nitrogen rate. It was also revealed that the maximum yield has already reached at 46 kg N ha^{-1} showing that there was no need to apply 69 and 92 kg N ha^{-1} in sesame in the study area. The lowest seed yield (0.58 t ha^{-1}) was recorded from the control treatment. Thus, the seed yield was increased by 217%, due to combined application of 10 t FYM ha^{-1} with 46 kg N ha^{-1} over control treatment.

Table 3. *Interaction effect of farmyard manure (FYM) and nitrogen (N) rates on thousand seed, grain yield, biomass, harvest index of sesame in 2022 cropping season*

FYM (t ha^{-1})	N (kg ha^{-1})	1000 seed weight (g)	Grain yield (t ha^{-1})	Biomass (t ha^{-1})	Harvest index
0	0	1.86^{d}	0.58^{g}	4.09^{e}	0.14^{e}
	46	3.73^{bc}	1.33^{de}	4.18^{e}	0.31^{a}
	69	3.60^{c}	1.20^{ef}	4.21^{e}	0.28^{ab}
	92	3.60^{c}	1.11^{f}	5.28^{d}	0.21^{cd}
5	0	3.56^{c}	1.34^{de}	5.51^{d}	0.24^{bc}
	46	3.83^{bc}	1.39^{de}	7.08^{c}	0.19^{d}
	69	3.60^{c}	1.39^{de}	7.98^{bc}	0.17^{de}
	92	3.60^{c}	1.45^{cd}	8.35^{ab}	0.17^{de}
10	0	3.93^{b}	1.36^{de}	4.93^{de}	0.28^{ab}
	46	4.40^{a}	1.84^{a}	8.46^{ab}	0.21^{cd}
	69	3.60^{c}	1.73^{ab}	8.64^{ab}	0.20^{d}
	92	3.60^{c}	1.63^{bc}	9.05^{a}	0.18^{de}
LSD $_{(0.05)}$		0.30	0.19	0.94	0.1
CV (%)		5.0	8.3	8.6	12.9

Means in columns and rows sharing the same letter(s) are not significantly different at 5% level of significance; LSD=Least Significant Difference; CV= Coefficient of Variation

The analysis of variance showed that the interaction effect of farmyard manure and nitrogen had significant ($P < 0.01$) effect on biomass and harvest index (Table 3). Plants grown under the treatment combination of 0 t FYM ha^{-1} and 0 kg N ha^{-1} produced the lowest biomass yield (4.09 t). However, the maximum biomass yield (9.05 t) was recorded when 10 t FYM ha^{-1} was combined with 92 kg N ha^{-1}. Biomass yield increased over control treatment by about 121.27% when 10 t FYM ha^{-1} was combined with 92 kg N ha^{-1}. The significantly higher harvest index (0.31) was obtained when 46 kg N ha^{-1} was applied alone than the other interactions. The significant decrease in harvest index at the highest nitrogen application rate (92 kg N ha^{-1}) than 46 kg N ha^{-1} in the absence of FYM might be due to contribution of nitrogen in enhancing more the vegetative growth and thus lower photo assimilate production and its ultimate partitioning into stover compared to partitioning in seed that proved detriment to seed yield. At the end, the grain produced at the levels of nutrients application was not high enough to increase the harvest index.

Economic Analysis

As shown in table 4, the result of partial budget analysis revealed that the highest net benefit (ETB 86,476.00 ha^{-1}) and MRR % (468.19) was obtained from 0 t FYM + 46 kg N ha^{-1} followed by the net benefit (ETB 83,290.00 ha^{-1}) and MRR % (410.04) from treatment 10 t FYM + 46 kg N ha^{-1}. The highest marginal rate of return was recorded from nil application of FYM with 46 kg N ha^{-1}. However, application of FYM is crucial to ameliorate the soil physical, chemical and biological properties the degraded soil thereby ensure sustainable sesame production in the area.

Table 4. *Partial budget for farmyard manure and nitrogen application in sesame at Gode in2022 cropping season*

Treatment (FYM t + N kg ha^{-1})	Average yield (kg ha^{-1})	Adjusted yield (kg ha^{-1}) (90%)	Gross benefit (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Marginal Rate of Return (MRR) (%)
0+0	583.30	524.97	41997.60	0.00	41997.60	-
0+46	1333.00	1199.70	95976.00	9500.00	86476.00	468.19
0+69	1207.00	1086.30	86904.00	14250.00	72654.00	D
0+92	1111.30	1000.17	80013.60	19000.00	61013.60	D
5+0	1342.70	1208.43	96674.40	25000.00	71674.40	177.68
5+46	1395.00	1255.50	100440.00	34500.00	65940.00	D
5+69	1391.00	1251.90	100152.00	39250.00	60902.00	D
5+92	1454.70	1309.23	104738.00	44000.00	60738.00	54.25
10+0	1369.00	1232.10	98568.00	40000.00	58568.00	D
10+46	1844.30	1659.87	132790.00	49500.00	83290.00	410.04
10+69	1737.00	1563.30	125064.00	54250.00	70814.00	D
10+92	1632.30	1469.07	117526.00	59000.00	58526.00	D

Therefore, the application of 10 t FYM + 46 kg N ha^{-1} with MRR % (410.04) is recommended in the test area. It indicates that each Birr 1.00 investment in sesame production, the producer can obtain Birr 1.00 and additional Birr 4.10. Based on this analysis it is advisable to apply the combination of 10 t FYM and 46 kg N ha^{-1} for this specific area to get more economic benefit.

Conclusion

The soils in the study area were low in nitrogen (N), phosphorous (P) and organic C, therefore, application of inorganic and organic fertilizer (such as farm yard manure) is advisable in the area. The community in the area are pastoralist and agro-pastoralists, thus they practice mixed farming (crop production and livestock rising). Thus, farm yard manure (FYM) is accessible and can be used to amend the degraded soil. The FYM apart from increasing crop yield could improve the soil physical, chemical and biological properties. Therefore, combined application of farm yard manure and nitrogen at rate of 10 t FYM and 46 kg N ha^{-1} is the optimum level for maximum yield with marginal rate of return (410.04 %). It indicates that each Birr 1.00 investment in sesame production, the producer or the farmer can obtain Birr 1.00 and additional Birr 4.10. Thus, the rate 10t FYM with 46 kg N ha^{-1} was found economically optimum rate to ensure sustainable sesame production in test area and in area with similar agro-ecology.

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