Journal of Rural Advancement
[ISSN 2347-2561 (P); 2583-6102 (E)]
Vol. 11, Issue 01, April 2023

Effect of farmyard manure, nitrogen and phosphorus on productivity, growth, water use efficiency and economics of tomato production in Hamelmalo, Eritrea

Goitom Semere, Woldeslassie Okubazghi and Balwan Singh

Department of Land Resources and Environment,
Hamelmalo Agricultural College, P.O. Box 397, Keren, Eritrea.

[Received on: Jan 09, 2023; Accepted on: Feb 06, 2023]

Abstract

In Eritrea the average yield of tomato is meager as farmers usually use inadequate and inappropriate proportions of nutrient inputs; therefore, to develop a better understanding of nutrient management, a field experiment was conducted at the research area of Hamelmalo Agricultural College, Eritrea with the objective to determine the effect of farmyard manure (FYM) and chemical fertilizers on growth, yield, water use efficiency and economics of tomato production. The experiment was laid down in a split plot design with FYM as the main plot; nitrogen (N) and phosphorus (P) combination levels in subplots with three replications. The FYM treatments were 0 and 10 t ha-1. N and P combination treatments were 0%, 75%, 100%, 125% and 150% of the recommended N and P dose. The recommended dose of N and P2O5 locally used was 120 kg and 80 kg ha-1, respectively. All the data collected were analyzed using Gen-stat software. The results showed that 10 t FYM ha-1 + 150 kg N and 100 kg P2O5 ha-1 had a significant effect on tomato yield, followed by 150 kg N and 100 kg P2O5 ha-1 alone. The water use efficiency of tomatoes was also significantly affected by the application of both FYM and inorganic fertilizers (N and P). The highest water use efficiency of tomato was recorded with the application of 10 t ha-1 FYM + 150 kg N and 100 kg P2O5 ha-1. Gross margin per nakfa analysis showed that applying 10 t FYM ha-1 along with 150 kg N and 100 kg P2O5 ha-1, was more economical.

Key words: FYM, nitrogen, phosphorus, water use efficiency, economics, yield, tomato.

Introduction

In Eritrea, tomato (Lycopersicon esculentum Mill.) is grown almost all over the country, mostly under irrigation (furrow, drip or spate irrigation) and sometimes under rain fed conditions. It is the most widely used vegetable as sauce, soup and salad, making the staple food more palatable. Tomato production has a long tradition among Eritrean farmers because of its high demand and reasonably good yield and return (Asgedom et al., 2011). However, the average yield of tomato still remains very low which is around 10 t ha^{-1} (MoA, 2015) compared even to the neighboring country, Kenya (23.2 t ha^{-1}), (FAO, 2013). Eritrean farmers normally use inadequate nutrient inputs, inappropriate proportions and inefficient combinations of fertilizers, which in turn increase the cost of inputs (MoA 2015). Productivity in Eritrea has been far below than in other developing country with similar agro-climatic conditions, mainly due to low nutrient status of soils (Negassi et al., 2002). Therefore, a better understanding of the nutrient requirement for tomato production is required in order to develop management strategies, which optimize fertilizer use by the crop thereby increasing returns to the farmers through increased yield. Thus, the present investigation was undertaken to study the effect of farmyard manure (FYM), nitrogen (N) and phosphorus (P) on yield, water use efficiency and economics of tomato production.

Materials and Methods

Site description

The field experiment was conducted under irrigation conditions in Hamelmalo Agricultural College (HAC), located at 150 52’18’’ N and 380 27’55’’ E, and an elevation of 1280 m above sea level in semi-arid agro-ecological region of Eritrea; annual average rainfall in the growing season was 436.3 mm, the maximum and minimum temperature of the research area were 34.7 0C and 11.1 0C, respectively (Meteorological observatory, HAC). Soil physico-chemical properties of the experimental field were determined before sowing using standard methods and procedures. The results of the phisico-chemical properties of composite sample of the area are presented in Table 1.

Table 1: The physico-chemical properties of the soil before sowing

Soil parameters	Value
Sand (%)	59.8
Silt (%)	26.6
Clay (%)	13.6
Textural class	Sandy loam
Bulk density (g cm^{-3})	1.65
Field capacity (%) by weight	11.6
EC (1:5) (dSm^{-1})	0.08
pH (1:5)	8.2
Organic matter (%)	0.49
Available nitrogen (%)	0.008
Extractable phosphorous (ppm)	2.7
Exchangeable potassium (cmolkg^{-1})	0.89
Exchangeable Ca (cmolkg^{-1})	26.5
Exchangeable Mg (cmolkg^{-1})	4.65
Exchangeable Na^{+}(cmolkg^{-1})	0.18
CEC (cmolkg^{-1})	28.6

Experimental design

A split-plot design was used with 10 treatments and three replications. The plot size was 3.0 m x 2.0 m and the spacing between row to row and plant to plant was 75 cm and 40 cm, respectively. The space between plots and blocks was 1.0 m and 1.5 m, respectively. Each plot was prepared with four rows of furrows and ridges. The ridges were 30 cm high and the length of the furrows and spacing between them were 2.0 m and 0.75 m, respectively. Two farmyard manure (FYM) levels as the main plot and five levels of nitrogen (N) and phosphorus (P) fertilizers combinations as the sub-plot were taken. The Riogrande variety of tomato was sown in the nursery on a flat seed bed one month before transplanting at a seed rate of 200 g per 250 m^2 of seedbed, with a spacing of 10 cm between rows. Weeding and irrigation practices were applied as and when required. Seedlings were transplanted 30 days after being sown in the nursery. The plants were spaced row to row 0.75 m apart and plant to plant 0.40 m apart, for a total of 20 plants per plot. Gap filling was done within 10 days after transplanting to replace the dead and weak plants. The plots were kept free of weeds by regular hand weeding and intercropping management practices. Fulldazim Wp 50% (a fungicide) was applied three times whenever the symptoms of collar rot (a fungal disease) were observed. Dimethox (an insecticide) was also applied twice to control pests. Pests like late blight, tuta absoluta and boll worm were observed during the crop season. The decomposed FYM was applied and incorporated into the soil two weeks before transplanting. All P and 26% of the total N fertilizer dose were added during transplanting. The other half of N fertilizer was applied in two split doses: one at 30 days after transplanting and the second at the stage of fruit setting. Irrigation scheduling was done at 50% soil moisture depletion.

Treatments

Farmyard manure (FYM): FYM0 = 0 t ha^{-1} and FYM1= 10 t ha^{-1}

NP fertilizer levels: T0 = 0% of the recommended N- P_2O_5 (0-0 Kg ha^{-1});

T1 = 75% of the recommended N- P_2O_5 (90-60 Kg ha^{-1});

T2 = 100% of the recommended N- P2O5 (120-80 Kg ha^{-1});

T3 = 125% of the recommended N- P_2O_5 (150–100 Kg ha^{-1});

T4 = 150% of the recommended N- P_2O_5 (180-120 Kg ha-1)

The recommended doses of nitrogen and phosphorus were 120 N kg ha^{-1} and 80 P_2O_5 Kg ha^{-1} (Asgedom et al., 2011).

The number of days to flowering of tomatoes was recorded as the number of days from transplanting to the time when 50% of the plants in each plot developed flowers. Cumulative numbers of fruits per plant at successive pickings were counted from four randomly selected plants in the net pot in each treatment and their average number was calculated. The weight of the fruits per plant was calculated by adding the weight of harvested fruits from four randomly selected plants at every picking within the net plot and their average weight was calculated and expressed as fruit weight per plant in kg. The cumulative total fruit harvested from successive pickings, including the non-marketable ones, was weighed per net plot and expressed in t ha^{-1}. From the total fruits harvested, all healthy fresh fruits free from cracks, insect damage and small-sized fruits were separated to calculate the marketable yield and expressed in t ha^{-1}. The rotten, insect-damaged, small sized and cracked fruits that could not be sold were weighed and expressed in proportion to the total harvested fruit yield.

Water use efficiency was calculated as marketable fresh fruit weight (kg ha^{-1}) obtained per unit volume of irrigation water applied (m^3 ha^{-1}) (Zotarelli et al., 2009).

The partial economic analysis was done using the partial budget procedure to determine the treatment that would give an acceptable return at low risk to the farmer (CIMMYT, 1988). The economic analysis of the data was done based on the prevailing farm gate prices of inputs, operations and outputs. The following concepts used in the partial budget analysis are defined as follows:

(The economic analysis was done using the partial budget procedure to determine the treatment that would give an acceptable return at low risk to the farmers (CIMMYT, 1988). The economic analysis of the data was done based on the prevailing farm gate prices of inputs, operations and outputs. The following concepts used in the partial budget analysis are defined under:)

Gross Revenue (GR) in Nakfa (local currency) ha^{-1} is the product of the average price of tomatoes and the total marketable yield for each treatment.

Total variable cost (TVC) in Nakfa ha^{-1} is the cost of labour and inputs, which include seeds, fertilizers and chemicals.

Gross margin (GM) in Nakfa ha^{-1} is the difference between gross revenue and total variable costs.

Gross margin per Nakfa invested is the gross margin divided by total variable cost (TVC).

Results and Discussion

Yield Parameters

The weight of fruits and total yield were significantly increased due to the application of FYM (Table 2). There was an increase in weight of fruits and total yield due to the application of FYM of 10.5% and 16.6%, respectively, over control. This could be due to FYM's ability to conserve soil moisture and supply nutrients. These results were in agreement with the observations of Bairagya et al. (2019), who reported that the combined application of FYM and vermicompost increased the total yield of tomatoes. Days to 50% flowering, number of fruits per plant, weight of fruits per plant, marketable yield, non-marketable yield and total yield of tomatoes were significantly affected by the application of N and P fertilizers (Table 2). Plants with treatments of 180 kg N and 120 kg P_2O_5 ha^{-1} produced the highest marketable yield (36.44 t ha^{-1}) and total yield (37.86 t ha^{-1}). In all the treatments, the control plot recorded the highest number of days to 50% flowering, the least number of fruits per plant, the weight of fruits per plant, marketable yield, non-marketable yield and total yield with values of 44.33, 17.41, 0.34 kg, 11.94 t ha^{-1}, 0.237 t ha^{-1} and 12.18 t ha^{-1}, respectively. The treatments that recorded the highest mean values could be due to the availability of N and P, which enabled the plant to have rapid vegetative growth and the development of reproductive parts, enhancing fruit development. These results were in agreement with the findings of Sigaye et al. (2022), reporting highly significant ($P < 0.01$) interaction effects of nitrogen and phosphorus fertilizer application during all growing seasons on total and marketable fruit yields of tomatoes.

The number of fruits and marketable yield were significantly affected due to the combined application of FYM and N-P combination levels (Table 2). However, there was no significant difference in days to 50% flowering, weight of fruits per plant, non-marketable yield or total yield of tomatoes among the combined use of FYM and inorganic fertilizers (N and P); however, the highest weight of fruits per plant (1.21 kg) and total yield (40.5 t ha^{-1}) were recorded with treatments 10t ha^{-1} FYM + 180 kg N and 120 kg P_2O_5 ha^{-1} and 10 t ha^{-1} FYM + 150 kg N and 100 kg P_2O_5

ha^{-1}, respectively. This could be explained on the basis of the ability of FYM to conserve moisture and the availability of nutrients in the soil due to the application of N and P fertilizers. Geremew et al. (2019) and Mohit et al. (2019) also reported similar results.

Table 2: Effect of FYM, N and P on days to 50% flowering, number of fruits per plant, weight of fruits per plant, marketable fruits, non-marketable fruits, total yield and water use efficiency of tomatoes

Treatment	Days to 50% flowering	Number of fruits per plant	Weight of fruits/ plant (kg)	Marketable fruit (t/ha)	Non marketable fruit (t/ha)	Total yield (t/ha)	Water use efficiency (kg/mm)
FYM0	41.27	24.65	0.76	23.69	1.091	24.79	34.85
FYM1	40.27	25.03	0.84	27.86	1.049	28.91	40.97
LSD (5%)	NS	NS	47.66*	NS	NS	1.589*	1.833*
CV (%)	5.5	4.9	4.3	1.4	11.3	1.7	1.4
T1	44.33	17.41	0.34	11.94	0.237	12.18	17.56
T2	44	23.76	0.66	21.65	0.902	22.55	31.84
T3	39	26.78	0.84	26.96	1.265	28.23	39.65
T4	41.17	30.07	1.03	36.44	1.423	37.86	53.58
T5	39.33	26.19	1.15	31.9	1.523	33.43	46.92
LSD (5%)	3.248*	3.107**	0.046**	0.717**	0.1446**	0.1446**	1.054**
FYM_0+T_1	46	14.66	0.31	10.2	0.247	10.45	15
FYM_0+T_2	41	24.72	0.62	19.87	0.92	20.79	29.23
FYM_0+T_3	39.33	24.55	0.8	25.18	1.27	26.45	37.03
FYM_0+T_4	41	31.05	0.98	33.72	1.493	35.22	49.59
FYM_0+T_5	39	28.27	1.1	29.49	1.527	31.02	43.37
FYM_1+T_1	42.67	20.16	0.37	13.68	0.227	13.91	20.12
FYM_1+T_2	39	22.79	0.7	23.43	0.883	24.31	34.45
FYM_1+T_3	38.67	28.99	0.87	28.74	1.26	30	42.26
FYM_1+T_4	41.33	29.1	1.07	39.15	1.353	40.5	57.57
FYM_1+T_5	39.67	24.12	1.21	34.31	1.52	35.83	50.46
LSD (5%)	NS	4.761*	NS	1.119*	NS	NS	1.645*
CV (%)	6.5	10.2	4.6	2.3	11	11	2.3
Grand mean		24.84	0.8	25.78	1.07	26.85	37.91

FYM = farmyard manure FYM_0 = 0 t ha-1, FYM_1 = 10 t ha$^{-1.}$
LSD (5%) = least significant difference at 5% CV = coefficient of variation
T_1 = N-P_2O_5 (0-0) kg ha^{-1} T_2 = N-P_2O_5 (90-60) kg ha^{-1} T_3 = N-P_2O_5 (120-80) kg ha^{-1}
T4 = N-P_2O_5 (150-100) kg ha^{-1} T_5 = N-P_2O_5 (180-120) kg ha^{-1} N = Nitrogen P = phosphorus; * = statistically significant; ** = statistically highly significant. NS = non-significant

Water use efficiency (WUE) of tomatoes

A perusal of the data in Table 2 revealed that the application of FYM had a significant effect on WUE. There was an increase of 17.6% in WUE due to the application of FYM. Similarly, application of FYM combined with N-P combination levels showed a significant change in the WUE of tomatoes. The highest mean value (57.57 kg mm^{-1}) was recorded with 10 t FYM ha^{-1} + 150 kg N and 100 kg P_2O_5 ha^{-1} and the lowest (15 kg mm^{-1}) in control (no inputs) with an average of 37.91 kg mm^{-1}. This could be due to the optimum availability of N and P and the improvement of soil physical conditions to conserve soil moisture. This observation justified the fact that WUE increased with an increase in yield due to the application of FYM, N and P fertilizers (Havlin et al., 2005). The application of N-P combination levels showed a highly significant difference in WUE. The highest mean value (53.58 kg mm^{-1}) was recorded with 180 kg N and 120 kg P_2O_5 ha^{-1} and the lowest value (17.56 kg mm^{-1}) in control.

Partial Economic Analysis

Results of the economic analysis (Table 3) showed that the highest gross margin (Nakfa) was obtained from treatment with 10 t ha^{-1} FYM + 150 kg N and 100 kg P_2O_5 ha-1, followed by 150 kg N and 100 kg P_2O_5 ha^{-1} application alone and the lowest was recorded in control (no inputs). From these results, it could be generalized that treatments with a high dose of the N and P combination level and the application of 10 t ha^{-1} FYM seemed to increase the total cost of production, whereas those with a lower dose and without FYM showed a lower cost of production. Other costs of production were equal for all treatments. The gross margin per one Nakfa ranked highest with 10 t ha^{-1} FYM + 180 kg N and 120 kg P_2O_5 application (3.135), followed by 180 kg N and 120 kg P_2O_5 application alone (2.936) and the lowest was in control (1.01), which were 243.6% and 220.7% higher, respectively, over the control. Thus, the interactive effect was more profitable than their individual effect under the conditions of the experiment. Heeralal et al. (2023) also reported that the application of integrated nutrient management significantly affected the growth, yield parameters and economics of tomato production.

Conclusion

The present investigation indicated some distinct benefits of combined use of organic and inorganic sources of fertilizers than one source alone. The results of this study showed that 10 t FYM ha^{-1} + 150 kg N and 100 kg P_2O_5 ha^{-1} application was most appropriate and economical for better yield of tomato under irrigation in Hamelmalo; this also supported the integrated nutrient management for tomato production. In addition the study revealed that application of FYM combined with N-P combination levels showed significant increase in WUE of tomato. The highest WUE (57.57 Kg mm^{-1}) was recorded in 10 t FYM ha^{-1}+ N-P_2O_5 (150-100) Kg ha^{-1}) application. Gross margin per Nakfa also increased with combined use of inorganic and organic fertilizers.

References

Asgedom S, Struik P C, Heuvelink E and Araya W. 2011. Opportunities and constraints of tomato production in Eritrea. *African J. Agricultural Research* **6**(4):956-967. [*DOI*]

Bairagya M D, Sarath K D. Maitra S. Roja M and Shankar T. 2019. Effect of FYM and vermicompost on yield and economics of rabi tomato (Lycopersicon esculentum). Int. *J. Agri. Sc.* **11**(7):8190-8192. [*DOI*]

CIMMYT. 1988. *From agronomic data to farmer recommendation: an* *economics training manual*. Completely revised edition, D.F. Mexico. [*DOI*]

Biramo G, Abera G and Biazin B. 2019. Effects of dry bioslurry and chemical fertilizers on tomato growth performance, fruit yield and soil properties under irrigated condition in Southern Ethiopian. *African J. Agricultural Research*. **14**(33):1685-1692.

Havlin J L, Beaton J D, Tsidale S L and Nelson W L. 2005. *Soil Fertility and Fertilizers: An Introduction to Nutrient Management*. 7th ed. New Jersey, Pearson Prentice Hall.

Table 3: Partial economic analysis of tomato yields due to application of farmyard manure, nitrogen, and phosphorus

Treatment	Total variable Cost (Nakfa) ha^{-1}	Gross Revenue (Nakfa) ha^{-1}	Gross margin (Nakfa) ha^{-1}	Gross margin (Nakfa) per Nakfa
FYM0	200000	592367	394472	1.897
FYM1	210000	696572	487678	2.251
T1	130000	298597	166164	1.245
T2	190000	541278	350002	1.825
T3	210000	674014	462791	2.188
T4	23000	910903	679732	2.936
T5	250000	797556	546687	2.175
FYM_0+T_1	130000	255083	128150	1.010
FYM_0+T_2	190000	496861	311085	1.675
FYM_0+T_3	210000	629528	423804	2.060
FYM_0+T_4	230000	843083	617413	2.736
FYM_0+T_5	250000	737278	491909	2.005
FYM_1+T_1	140000	342111	204178	1.480
FYM_1+T_2	200000	585694	388919	1.976
FYM_1+T_3	220000	718500	501777	2.135
FYM_1+T_4	240000	978722	742051	3.135
FYM_1+T_5	260000	857833	601465	2.346

FYM = Farmyard manure; FYM_0 = 0 t ha^{-1} FYM_1 = 10 t ha^{-1}; LSD (5%) = Least significant difference at 5%; CV = Coefficient of Variation; T_1 = N- P_2O_5 (0-0) kg ha^{-1}; T_2 = N- P_2O_5 (90-60) kg ha^{-1}; T_3 = N- P_2O_5 (120-80) kg ha^{-1}; T_4 = N- P_2O_5 (150-100) kg ha^{-1}; T_5 = N- P_2O_5 (180-120) kg ha^{-1}

Heeralal S, Tailor S P, Kuldeep S R and Keshav P K. 2023. Effect of integrated nutrient management on the growth, yield parameters and economics in tomato (*Lycopersicon esculentum* L.) under Southern Rajasthan conditions. *The Pharma Innovation Journal*. **12**(3):321-326.

FAO. 2013. *Production year book*. FAO, Rome. [*DOI*]

Sigaye M H, Lulie B, Mekuria R and Kebede K. 2022. Effects of Nitrogen and Phosphorus Fertilization Rates on Tomato Yield and Partial Factor productivity

Under Irrigation Condition in Southern, Ethiopia. *Food and Nutrition Science*. **6**: 57-65. [*DOI*]

Mohit M K, Singh M K, Singh S P and Naresh R K., 2019. Effect of integrated use of organic and inorganic sources of nutrients on growth, yield quality and profitability of tomato (Lycopersicon Esculentum Mill.) VAR. Pusa Rohini. *Int. J. Agricult. Stat. Sci*. **15**(1): 57-66. [*DOI*]

MOA. 2015. Annual Report of Ministry of Agriculture, Asmara, Eritrea.

Negassi A, Tangnas B, Bein E and Gebrus. K. 2002. Soil and Water Conservation Manual for Eritrea. Regional Land Management Unit (RELMA)/Sida, Nairobi. pp. 3. Nigerian Typic Haplustult amended with fresh and burnt rice mill wastes. *Bioresource Tech.* **76**:265-272.

Zotarelli L, Scholberg J M b, Dukes M D, Muñoz-Carpena R and Icerman J. 2009. Tomato yield, biomass accumulation, root distribution and irrigation water use efficiency on a sandy soil, as affected by nitrogen rate and irrigation scheduling. *Agricultural water management* **96**:23-34. [*DOI*]