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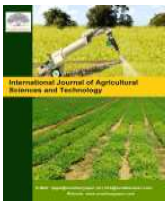

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Effect of Staking, Mulching, and Organic Manure on Tomato Yield and Yield Components at Fedis, East Hararghe Zone

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Abstract

Tomato is one of the most popular and widely grown vegetable crops in the world. However, its yield and production are highly constrained by several factors in Ethiopia. The objective of this study is to evaluate the influence of staking, mulching, and organic manures on the yield and yield component of tomatoes in the study area. The study was conducted in the Boko research site of the Fedis Agricultural Research Center. The experimental design was a randomized complete block with three replications for thirteen treatments. The combined analysis of variance revealed significant differences among the treatments for all parameters. Results stated that Pm+S+Um was better than other treatments in terms of plant height, number of branches per plant, number of clusters per plant, number of fruits per cluster, average fruit weight, and marketable yield. Considering the results it can be concluded that Pm+S+Um is more efficient for better growth and yield contributing characters compared to other treatments. Accordingly, the use of Pm+S+Um advanced marketable yield by about 90.77% over the control and economic returns (801875 ETB ha^{-1}). Therefore, Pm+S+UM was recommended for tomato production in the study area and similar agro-ecology.

Keywords: *Organic manure, Mulching, Tomato, Staking*

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely grown vegetable crops in the world. The tomato began its history in the coastal highlands of Western parts of South America (Tracy and Robins, 2004). Today, tomatoes are grown commercially in 159 countries. It's well-known that a healthy diet is important for preventing chronic diseases such as cancer, cardiovascular disease, cognitive function, and osteoporosis, as well as improving antioxidant levels and controlling body weight (Ali *et al*., 2020). Tomato requires warm, clear dry conditions and an altitude ranging between 700 and 2000 meters above sea level. The optimum growing temperature in the central lowlands of Ethiopia ranges between 24 ^{0}C and 28 ^{0}C during the day and 14 ^{0}C and 17 ^{0}C at night. High temperatures above 40 ^{0}C during the day and 22 ^{0}C at night can cause flower drops. Friable and sandy loam soil with a pH of 5.8-6.8 is favorable for high fruit yield (Lemma, 2002).

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The importance of tomatoes in Ethiopia is increasing and since it is a high-value commodity, it has been given priority in the national research system (Tsedeke, 2007). It is widely accepted and commonly used in a variety of ways as raw, cooked, or processed products more than any other vegetable. The national average tomato fruit yield in Ethiopia is often low (62.45 ha^{-1}) compared to the neighboring African countries like Kenya (236 ha^{-1}) and Sudan (124.97 t ha^{-1}) (FAO, 2021). The tomato yield and production are highly constrained by several factors in Ethiopia. Among these, poor soil fertility, lack of well-adapted improved varieties, lack of adequate nutrient supply, and poor agronomic management practices (staking, spacing, planting time, and irrigation) are the main constraints to agricultural production systems in low-input agriculture in the country (Gelmesa *et al*., 2012).

Staking is a means of providing support to ensure clean and unblemished fruits which keeps fruits off the ground, minimizing diseases and rotting of fruits thereby increasing marketable yield (Lamptey and Koomson, 2021). The marketable yield of tomatoes under wet conditions was significantly increased by the staking of tomato plants (Sowley and Damba, 2013). The use of mulches offers great hope because of their moisture-conserving ability and also, their moderate soil temperature (Ogundare *et al*., 2015). Mulching serves various purposes, increases soil temperature, reduces water evaporation, enhances fertilizer efficiency, improves solar light irradiation efficiency, improves soil physical and chemical properties, and improves soil microbial activity (Van Der Zee *et al*., 2017). The application of chemical fertilizers is currently one of the most commonly used methods in intensive agriculture (Da Costa *et al*., 2013). However, the long-term application of chemical fertilizers can cause many negative effects. For example, most of the nutrients added to the soil are not absorbed by plants. Studies have shown that more than 50% of the nitrogen and 90% of the phosphorus in chemical fertilizers are lost to the atmosphere or water sources (Simpson *et al*., 2011), resulting in greenhouse gas emissions, water eutrophication, and other environmental issues (Lam *et al*., 2017).

Chemical fertilizers are not the most appropriate solution to overcome these constraints, Use of chemical fertilizers is also expensive and a threat to human health (Zulfiqar *et al*., 2019). To maximize the efficiency of photosynthesis and minimize the risk of disease, each tomato leaf must have plenty of room and be supported up off the ground (Gopinath *et al*., 2017). The use of organic fertilizers is environmentally friendly since they are from organic sources and the best solution for increasing tomato yield is to use organic fertilizers (Oyewole *et al*., 2012). In general, the role of mulching, staking, and organic fertilizer on tomato growth and yield properties has not been studied in the study area. Hence, this study was conducted with the objectives of evaluating the influence of staking, mulching, and organic manures on the yield and yield component of tomatoes in the study area.

2. Material and Methods

2.1. Description of the Study Area

The study was conducted in the Boko research site of the Fedis agricultural research center during 2019 and 2021 cropping seasons for two years. The sites have bimodal rainfall distribution and are representatives of a sub-humid mid-altitude agro-climatic zone. The area is situated at a distance of about 24 km from Harar town in the southern direction. Fedis is located at the latitude of 09° 07'North and longitude of 042° 04'East, and an altitude of 1702 meters above sea level, with a prevalence of lowlands. The mean rainfall is about 801.3 mm for the last seven years (2015 to 2021). The mean maximum and minimum annual temperatures are 27.7 and 11.3°C, respectively, for the last seven years (2015 to 2021) (FARC, 2021).

2.2. Experimental Design and Treatments

The effects of mulching, staking, and organic manure were investigated using the tomato variety of Melka shola. The recommended rate of poultry manure (10 t ha^{-1}), cow dung (20 t ha^{-1}), and vermicompost (5 t ha^{-1}) were used for the experiment. The manure was incorporated into the soil two weeks before transplanting. Plants were staked at three weeks after transplanting with ropes. Grasses were used for mulching. The experiment was laid out in a randomized complete block design with three replications. The treatments consist thirteen treatment combination including control (Table 1). Each plot size was 2.1 m long and 2.25 m wide consisting of four rows and the overall experimental area was 8.75 m x 25.5 m (223.125 m^2). The transplanted tomato seedlings were planted directly in rows with a spacing of 70 cm between rows and 30 cm between plants. The spacing between blocks and plots was 1m and 0.5 m apart, respectively.

Table 1: Treatment Combination	
No	Treatment Combination
T1	Cow dung + Staking + Mulching
T2	Cow dung + Staking + Un-mulching
T3	Cow dung + Un-staking + Mulching
T4	Cow dung + Un-staking + Un-mulching
T5	Poultry manure + Staking + Mulching
T6	Poultry manure + Staking + Un-mulching
T7	Poultry manure + Un-staking + Mulching
T8	Poultry manure + Un-staking + Un-mulching
T9	Vermicompost + Staking + Mulching
T10	Vermicompost + Staking + Un-mulching
T11	Vermicompost + Un-staking + Mulching
T12	Vermicompost + Un-staking + Un-mulching
T13(Control)	Without (Staking, Mulching, and Organic Manure)

2.3. Data Collection

Agronomic data like flowering date, maturity date, plant height, number of branches per plant, number of bench per plant, number of clusters per bench, number of fruits per cluster, and fruit weight were collected using the ten randomly taken plants from the central two rows of each plot. Whereas marketable and non-marketable yields were conducted based on plots. The fruits were grouped into marketable and non-marketable. Fruits that were cracked and damaged by diseases, insects, and birds, very small-sized were considered non-marketable while fruits free of such damages were considered marketable and measured using a sensitive balance immediately after harvesting.

2.4. Soil Sampling and Analysis

Soil samples were taken in zigzag pattern before planting randomly from the experimental site at a depth of 0-30 cm using an auger and the sample was mixed thoroughly to produce one representative composite sample before sowing. About 1kg of the composite sample was taken using a polyethylene bag and taken to the soil laboratory for testing of caution exchange. The collected soil sample was labeled and packed in a plastic bag and taken to the Horticoop and plant laboratory. Before laboratory analysis, samples were air-dried, ground, sieved through a 2 mm sieve, and used for the analysis of soil.

3. Statistical Analysis

All collected data from the experiment at different growth stages were statistically analyzed by R software. To identify the differences between means least significant difference was used to compare treatment means at a 5% level of significance.

3.1. Partial Budget Analysis

Fruit yield from experimental plots was adjusted downward by 10% for management differences, to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. Accordingly, the mean fruit yields for treatment combinations were subjected to a discrete economic analysis using the procedure recommended by CIMMYT (1988).

Average yield (AY) (t ha^{-1}): It is an average yield of each treatment converted to t ha^{-1}.

Adjusted yield (AJY): The adjusted yield for a treatment is the average yield adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. AJY = AY - (AY × 0.10).

Gross field benefit (GFB): The gross field benefit for each treatment was calculated by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield. GFB = AJY x field/farm gate price of a crop.

Total variable costs (TVC): This is the sum of all the costs that vary for a particular treatment. The total costs that varied included the cost of organic fertilizer, Mulching, staking and the application cost.

Net benefit (NB): This was calculated by subtracting the total variable costs from the gross field benefit for each treatment. NB = GFB – TVC.

Dominance analysis (D): This was carried out by first listing the treatments in order of increasing costs that vary. Any treatment that has net benefit that were less or equal to those of a treatment with lower costs that vary were considered as dominated.

Marginal rate of return (MRR): This was computed by dividing the marginal net benefit (i.e., the change in net benefits) with the marginal cost (i.e., the change in costs) multiplied by hundred and expressed as a percentage:

$$MRR = \frac{Change\ in\ NB}{Change\ TVC} * 100$$

4. Results and Discussion

The physico-chemical properties of the study area are shown in Table 2. The soil was predominantly clay. The soil is generally basic with a pH of 9.01. The organic carbon (OC) content was moderate with a value of 1.53%, and the total

Table 2: Physico-chemical Properties of Soil Sample of the Experimental Site and Organic Manure Used

Properties	Soil Samples	Vermicompost	Poultry Manure	Cow Dung
Sand (%)	22	-	-	-
Clay (%)	60	-	-	-
Silt (%)	18	-	-	-
PH-H_2O	9.01	8.17	8.76	8.11
EC (mS/cm)	0.20	4.04	3.07	1.20
Ca^{2+} (ppm)	19,466.70	10,492.00	16,478.50	14,341.40
Mg^{2+} (ppm)	970.56	2,494.68	4,779.91	2,455.57
Na^{+} (ppm)	37.34	1,893.58	1,307.70	428.10
K^{+} (ppm)	268.64	8,024.44	8,539.35	3,760.68
P (ppm)	2.83	21.12	3,434.40	948.30
S (ppm)	19.54	46.23	1,386.97	93.99
Fe (ppm)	47.08	70.19	445.21	156.33
Mn (ppm)	145.91	125.58	135.87	124.34
Zn (ppm)	7.02	45.13	151.71	54.30
OC%	1.53	21.66	10.65	15.96
TN %	0.10	1.42	1.36	1.17
C:N (C/N)	16.11	15.31	7.84	13.69
CEC (Cmol+/kg soil)	53.19	38.89	32.72	38.76

nitrogen content was low with a value of 0.1%. The available P was equally low with a value of 2.83 mg/kg. The values obtained for K (268.64 mg/kg) and ECEC (53.19 Meq/100 soil) were high. Ca, Mg, Na, K, and Mn were high in the study area. Indicate the study area has reached for those nutrients which essential for plant growth and development.

The physico-chemical properties of the vermicompost are shown in Table 2. The organic carbon (OC) and total nitrogen content were high with values of 21% and 1.42%, respectively. The available P was in the target range with a value of 21 mg/kg. The exchangeable cations were high in status with values of 19,466.7 mg/kg for Ca, 2,494.64 mg/kg for Mg, 1,893.58 mg/kg for Na, and 8,024.44 mg/kg for K, 19.54 mg/kg for S, 125.58 mg/kg for Mn. The values obtained for ECEC (38.89 Meq/100 soil) were high. Indicate the addition of organic matter will increase the CEC of soil. The physico-chemical properties of the cow dung are shown in Table 2. The organic carbon (OC) and total nitrogen content were high with values of 15% and 1.75%, respectively. The available P was in the target range with a value of 948.3 mg/kg. The exchangeable cations were high in status with values of 14,341.4 mg/kg for Ca, 2,455.57 mg/kg for Mg, 428.1 mg/kg for Na, 3,760.68 mg/kg for K, 93.99 mg/kg for S, and 124.34 mg/kg for Mn. The values obtained for CEC (38.76 Meq/100 soil) were high.

The physico-chemical properties of the poultry manure are shown in Table 2. The organic carbon (OC) and total nitrogen content were high with values of 10% and 1.36%, respectively. The available P was in the target range with a value of 3,434.4 mg/kg. The exchangeable cations were high in status with values of 16,478.5 mg/kg for Ca, 4,779.9 mg/kg for Mg, 1,307.7 mg/kg for Na, and 8,539.35 mg/kg for K, 1,386.97 mg/kg for S, 1135.87 mg/kg for Mn. The values obtained for CEC (32.7 Meq/100 soil) were high. Indicate the addition of organic matter will increase the CEC of soil. In general, the application of poultry manure had a high amount of macronutrients (N, P, and S) and micronutrients (Ca, Mg, K, Fe, Mn, and Z), which shows improved soil fertility and increased tomato yield.

4.1. Flowering and Maturity Date

Significant variation was found among the treatments in terms of flowering and maturity date. The latest flowering date (42.67 days) was recorded for Pm+S+Um whereas the earliest flowering date (36.33 days) was recorded for Cd+Us+Um. The latest maturity date (82.62 days) was recorded from Pm+S+Um whereas the earliest flowering date (77.33 days) was recorded from Cd+Us+M, Cd+Us+Um, Cd+S+UM, Cd+Us+Um, and Vc+S+M.

4.2. Plant Height and Branches per Plant

Statistically significant variation was found due to the effects of treatments on the plant height and branches per plant (Table 3). The maximum plant height (68.50 cm) was obtained from Pm+Us+M followed by Pm+S+Um (40.59 cm) and the minimum (55.33 cm) was achieved from Vc+Us+M. The maximum number of branches (5.88) was recorded from Pm+S+Um. Whereas the minimum number of branches (3.05) was found from Vc+Us+M. This agreed with the work of Direkvandi *et al*. (2008) and Ayeni (2014) who reported a significant increase in plant height and number of branches as a result of the application of poultry manure. Sowley and Damba (2013) reported that several branches were affected by staking. The present investigation also agreed with the findings of Ilodibia and Chukwuma (2015) who reported a significant increase in plant height, number of branches, and number of leaves as a result of the application of poultry manure.

4.3. Cluster per Plant and Number of Fruit per Cluster

The number of clusters per plant was significantly influenced by the treatments (Table 3). Maximum cluster per plant (13.16) was recorded from Pm+S+Um. Whereas the minimum cluster per plant (4.88) was found from Vc+Us+M. This may be attributed to the sufficient release of nutrients particularly N.P.K contain in the poultry manure applied, as these nutrients improve the growth and yield of crops. Similarly, a higher number of fruit per plant was recorded in a staked plant, studied by Ali and Moniruzzaman (2017).

4.4. Fruit Weight, Marketable Yield, and Unmarketable Yield

Statistically significant variation was found due to the effects of treatments on the number of fruits per plant, marketable yield, and unmarketable yield (Table 3). The average maximum fruit weight (58.80 g) was obtained from Pm+S+Um followed by Pm+S+M (55.60 g) and the average minimum fruit weight (41.53 g) was given in control. This is in line with the findings of Ghorbani *et al*. (2008) who reported that tomato fruit weight. Alam *et al*. (2016) reported maximum yield per plant and total yield in staking. Maximum marketable yield (36.15 t ha^{-1}) was recorded from Pm+S+Um followed by

Pm+S+M (31.71 t ha^{-1}) whereas the lowest data (18.95 t ha^{-1}) were noticed from the control. This may be attributed to the sufficient release of nutrients particularly N.P.K contained in the poultry manure applied, as these nutrients improve the yield of tomato. Staking may provide support to ensure clean and unblemished fruits which keep fruit away from the ground, minimizing diseases and rotting of fruit thereby increasing marketable yield. The maximum unmarketable yield (4.61 t ha^{-1}) was recorded from Pm+S+Um followed by Pm+Us+M (4.55 t ha^{-1}) whereas the lowest yield (1.74 t ha^{-1}) was noticed from the control. This agreed with the finding of Agbede *et al*. (2019) who reported that fruit and fruit quality is improved as a result of the application of poultry manure. Al Amin *et al*. (2017) reported that yield and yield-related traits are affected by mulching and the application of organic manure. A higher number of fruits per plant, days to maturity, weight of a single fruit, and total yield were recorded in the staked plant, studied by Ali and Moniruzzaman (2017).

Table 3: Combined Mean of Yield and Yield Component of Tomato

Treatments	FD	MD	PH(cm)	NBPP	NCPP	NFPC	AFW(g)	MY(t ha^{-1})	UMY(t ha^{-1})
Pm+S+Um	42.67^{a}	82.67^{a}	68.06^{a}	5.88^{a}	13.16^{a}	4.62^{ab}	58.80^{a}	36.15^{a}	4.61^{a}
Pm+S+M	42.00^{a}	82.50^{a}	67.44^{a}	5.22^{abc}	10.16^{b}	4.23^{abc}	55.60^{a}	31.71^{ab}	1.97^{bc}
Pm+Us+M	42.00a	82.00^{ab}	67.28^{a}	5.76^{ab}	7.97^{b}	4.72^{a}	54.87^{a}	30.81^{abc}	4.55^{a}
Cd+Us+M	38.00^{bcd}	77.33^{c}	61.28^{a-d}	4.44^{cd}	8.17^{b-e}	4.02^{abc}	54.50^{a}	30.68^{abc}	2.98^{abc}
Pm+Us+M	36.33^{cd}	80.00^{abc}	68.50^{a}	4.95^{abc}	9.34^{bc}	4.18^{abc}	54.07^{ab}	27.71^{bcd}	3.68^{ab}
Cd+S+UM	37.67^{bcd}	77.33^{c}	62.67^{a-d}	4.44^{cd}	7.62^{c-f}	3.55^{abc}	54.70^{a}	27.05^{bcd}	3.40^{abc}
Cd+S+M	36.33^{cd}	77.33^{c}	63.72^{abc}	4.44^{cd}	6.78^{d-g}	4.10^{abc}	53.53^{ab}	26.82^{bcd}	1.94^{c}
Cd+Us+Um	34.33^{d}	77.33^{c}	66.44^{ab}	4.65^{bcd}	8.44^{bcd}	3.40^{abc}	56.60^{a}	25.90^{b-e}	2.75^{bc}
Vc+S+M	40.33^{ab}	77.33^{c}	57.17^{bcd}	3.72^{de}	6.89^{d-g}	3.28^{bc}	46.27^{ab}	25.86^{b-e}	2.73^{bc}
Vc+Us+M	37.33^{bcd}	79.00^{c}	62.28^{a-d}	3.05^{e}	6.89^{d-g}	3.45^{abc}	54.67^{a}	23.73^{cde}	2.51^{bc}
Vc+Us+M	39.33^{abc}	79.33^{bc}	55.33^{cd}	3.23^{e}	4.88^{g}	3.55^{abc}	56.70^{a}	23.09^{de}	2.49^{bc}
Vc+St+Um	38.00^{bcd}	78.67^{c}	55.67^{cd}	3.51^{de}	5.94^{fg}	4.17^{abc}	49.33^{ab}	20.63^{de}	2.17^{bc}
Control	39.33^{abc}	80.00^{abc}	53.83^{d}	3.26^{e}	6.27^{efg}	3.05^{c}	41.53^{b}	18.95^{e}	1.74^{c}
CV (%)	13.27	7.05	20.45	11.78	16.46	14.47	19.23	18.75	13.67
LSD (5%)	3.89	2.73	9.83	1.15	2.05	1.34	12.86	7.19	1.74

Key: Pm=poultry manure, S=staking, Us=unstacking, M= mulching, Um=unmalting, Cd=caw dung, Vc=Vermicomposting, FD=flowering date, MD=maturity date, PH=plant height, NBPP=number of branch per plant, NCPP=number of cluster per plant, NFPC=number of fruit per plant, AFW=average fruit weight, MY=marketable yield, UMY=un marketable yield. Similar letters do not differ at a 5% probability and dissimilar letters differ at a 5% probability level.

4.5. Partial Budget Analysis

The partial cost analysis was conducted based on the average price fluctuation of Tomato in two years presented in Table 4. At the local market, the price of tomato was about 25 birr kg-^{1} but fluctuated over time. The total variable costs were the price of organic manure (poultry manure, cow dung, vermicompost), staking, and mulching. The cost of (poultry manure was 1.5 ETB/kg, cow dung was 0.4 ETB/kg, vermicompost was 1.5 ETB/kg, staking was 2 ETB/1tree, mulching was 5 ETB/ human careering), application 30 laborers/ha, each 75ETB/day and the market price of tomato was 25ETB/kg. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation for farmers. The use of poultry manure with staking resulted in a net return of 801875 birr ha^{-1} (Table 4).

Table 4: Partial Budget Analysis of Staking, Mulching, and Organic Manure on Tomato Production

Treatments	UY(t ha^{-1})	AY(t ha^{-1})	GFB (birr ha^{-1})	TVC (birr ha^{-1})	NB (birr ha^{-1})	MRR (%)
Control	18.95	17.055	426,375	0	426,375	
Vc+Us+Um	20.63	18.567	464,175	3,750	460,425	908
Pm+Us+Um	27.71	24.939	623,475	7,500	61,5975	4148
Vc+S+Um	23.09	20.781	519,525	7,750	511,775	D
Cd+Us+Um	25.9	23.31	58,2750	8000	574,750	25190
Vc+Us+M	23.73	21.357	533,925	9,305.55	524,619.5	D
Pm+S+Um	36.15	32.535	813,375	11,500	801,875	12634.4
Cd+S+UM	27.05	24.345	608,625	12,000	596,625	D
Pm+Us+M	30.81	27.729	693,225	13,055.55	680,169.5	7914.784
Vc+S+M	25.86	23.274	581,850	13,305.55	568,544.5	D
Cd+Us+M	30.68	27.612	690,300	13,555.55	676,744.5	43,280
Pm+S+M	31.71	28.539	713,475	17,055.55	696,419.5	562.1429
Cd+S+M	26.82	24.138	603,450	17,555.55	585,894.5	D

Key: UTY=unadjusted yield, AY=adjusted yield, GFR=gross field benefit, TVC=total variable cost, NR=net benefit, MRR=marginal rate of return.

5. Conclusion and Recommendation

As indicated in the results there were significant differences among the treatments for all parameters. Results stated that Pm+S+Um was better than other treatments in terms of plant height, number of branches per plant, number of cluster plants, number of fruits per cluster, average fruit weight, and marketable yield. Considering the results it can be concluded that Pm+S+Um is more efficient for better growth and yield contributing characters compared to other treatments. Accordingly, the use of Pm+S+Um advanced marketable yield (36.15 t ha^{-1}) by about 90.77% over the control (18.95 t ha^{-1}) and economic returns (801875 ETB ha^{-1}) with acceptable marginal rate of return. Therefore, Pm+S+UM was recommended for yield increment of tomato production for study area and similar agro-ecology.

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