Impacts of Effective Good Agricultural Practices on the Performances of Tomato (*Solanum lycopersicum*) Varieties and Pest Management

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ABSTRACT

Tomato is one of the major vegetable crops grown in Ethiopia; but its production and productivity is low compared to the world average; due to shortage of improved tomato cultivars, lack of effective agronomic practices, pests and diseases. Thus, the study was initiated to evaluate the effect of effective good agricultural practices on the performances of tomato varieties and management of pests. Two tomato cultivars (ARP Tomato D2 and Galilea) and five Good Agricultural Practices (GAPs): Control, GAPs1, GAPs2, GAPs3 and Farmer practice (FP) were tested in randomized complete block design in three replications. The analysis of variance indicated that the main and interaction effects of GAPs and variety showed significant differences ($p<0.05$) on growth and yield parameters. Days to 90% maturity was increased on FP plot and decreased on GAPs3 and GAPs2 plots for both varieties. Highest tomato height (107cm), maximum primary(8.6) and secondary(16.50) branches were recorded from FP plot. Maximum number of fruit per cluster (4.56), fruit length (215.33mm), fruit number (47.00), fruit weight (1068.20g) and fruit width (205.30mm) were recorded from FP plot. Maximum marketable yield (512.6 q ha^{-1}) was recorded from the plot received GAPs3. Also, maximum total fruit yields (584.6 and 557.16 q ha^{-1}) were produced from FP plot and GAPs3 applied, respectively and lowest fruit yield (342.33 qha^{-1}) was produced on the control plot for the two tomato varieties studied. The variety Galilea has significantly produced higher marketable and total yields (440.7 and 504.04 qt ha^{-1}) as compared ARP tomato D2 variety (395.6 and 454.75 qt ha^{-1}), respectively. Highest pH values (4.88 and 4.60) were obtained from ARP tomato D2 and Gelilea varieties with GAPs3 treatment and lowest pH value (2.13) was recorded from FP plot. The greatest net income (257,481 Eth. Birr) and benefit-to-cost ratio (2.7) along with better marginal rate of return (424.8%) was also obtained from both varieties with an application of GAPs3. Thus, from the *study results, it is possible to conclude that the application of GAPs3 (Compost at 15 t ha^{-1} + mulching with 15cm(8kg) thickness + YST + BST) to tomato varieties had significantly improved the production and productivity of tomato crops in the study area; though Gelilea variety is more productive than ARP tomato D2 variety in the study area. However, this study should be again confirmed on farmers' field for practical recommendations.*

***Keywords**: Good Agricultural Practices, Tomato varieties, Yields, Pests control*

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely grown vegetable crops in the world (Mersha, 2008). As an essential source of minerals, vitamins and health acids, tomato is one of the most essential vegetable crops of Solanaceae grown universally. Tomato is a vegetable crop of large importance throughout the world (Abdussamee *et al.,* 2014; Kaur *et al*., 2014; Mehraj *et al*., 2014). It is cultivated in different major growing areas of Ethiopia. World tomato production reached to nearly 186.82 million tons from total area of 5 million hectare with an average productivity of 36.97 t/ha (FAOSTAT, 2022). In Ethiopia, tomato ranks fourth in total production (5.45%) after Ethiopian cabbage, red pepper and green pepper. However, its national mean yield was low (5.81 and 6.52 t ha^{-1}) in 2019 and 2020 respectively as compare to other countries (CSA, 2020). Among vegetable crops, tomato has very high nutritive values because of better contents of vitamins A, B and C, including calcium, iron and other minerals (**Jones, 2007; Ashrafuzzaman *et al*., 2010**). Particular nutrients found in abundance in tomatoes, mainly lycopene, flavonoids and chlorogenic acids, have headlines for their sickness-preventing abilities which are effective antioxidants and assist to protect the cells in our bodies from harm caused by cancer or degenerative and age-related diseases.

The production and productivity of tomatoes in Ethiopia are highly limited by numerous factors. Among these, the lack of variety that is adaptable to different agro-ecology, poor quality seeds, diseases and insect pests, high postharvest loss, lack of awareness of present improved technology and poor marketing system are some of the main constraints related to tomato production in Ethiopia (Lemma, 2002). Furthermore, in the main tomato production belt of the central rift valley of Ethiopia excessive temperature, diseases, bad irrigation practices and fertilization are some of the limitations to reducing normal vegetative and reproductive organs development for correct fruit settings and maturation (Dandena *et al.,* 2011).

The unsustainable economic ability of small holder farmers lead to the insufficient rates of chemical fertilizers application for the crop production (Girma, 2001). The farmers want to use optimum chemical fertilizers to grow their crop; however, if only mineral fertilizers are constantly implemented in the soil without adding organic manure, the productivity of land will decline because of the depletion of soil microbial biomass and activity. The use of chemical fertilizers is also high-priced and a hazard to human health and spraying pesticides is a highly common behavior of vegetable farmers. Misuse and overuse of pesticides are dangerous to the health of farmers in addition to the environment (Negatu *et al*., 2021). The excessive pesticide residue concentrations located on vegetables are dangerous to consumers. Because fruits and vegetables are often traded and consumed in fresh forms, biological contamination and pesticide residue are severe to human health (Negatu *et al*., 2021). So, it is suggested that there should be an emphasis on finding options for chemical fertilizers and synthetic pesticides including correct agricultural practices (compost, biopesticide, mulching and sticky trap), which are less expensive than different sources of nutrients and relatively safe.

Good Agricultural practices (GAP) (mulching, composting, sticky trap and biopesticides) are the main techniques for insect and disease management. Pesticide use, besides being has negative impact on the environment and human health, additionally increases the price of production making this humble vegetable high-priced for poor consumers. The share of the price of pesticide to total material input price is 55% for eggplant, 49% for cabbage and 31% for tomato (Orden *et al*., 1994). Many pesticides usually available in Ethiopia are categorized by the World Health Organization as extremely dangerous and are either banned or seriously restricted for use in the developed world. The health prices incurred by farmers exposed to pesticides are 61% better than those of farmers who aren't exposed (AVRDC, 2002).

The use of organic sources has a role in the management of plant diseases and soil fertility in the field and greenhouse (Muhammad, 2011). Therefore, emphasizing locally available low-price organic manure becomes an attractive option. Proper use of compost can reduce the dependency of many farmers on an increasing number of high-priced chemical fertilizers. Balanced use of both macro and micronutrients for crops performs a significant role in growing yields; it may not be available from chemical fertilizers. The use of compost together with low rates of mineral fertilizers could be an alternative solution for sustainable fertility management and promote food self-sufficiency, especially for resource-poor farmers and also increase the efficiency of organic fertilizers.

The repeated use of high doses and increased spray frequency of pesticides on vegetables by smallholder tomato farmers in rift valley areas of Oromia, Ethiopia has led to severe ecological consequences like the destruction of natural fauna, adverse effects on non-target organisms, increased pesticide residues in the harvested produce as well as selecting for insecticide resistance in pesticide use practices provide an opportunity to identify eco-friendly, safer, and sustainable methods of pest control especially with the increasing demand for vegetables in expanding African cities and for export (Negatu *et al*., 2021). One of the sustainable ecologically friendly approaches is the use of good agricultural practices. Thus, the objective of this study was to evaluate the effect of using good agricultural practices on tomato varieties' performances and pests control at Melkassa Agricultural Research Center in Adama District, Oromia, Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Melkassa Agricultural Research Center (MARC) in the central rift valley of Ethiopia during 2021 rainy season and supplemented with irrigation. Melkassa is located 115 km away from Addis Ababa. It is also located at 8^o 24' N latitude, 39^o 19' E longitude and an altitude of 1540 meters above sea level. It is found in the East Showa zone along the Rift valley. The area is characterized by low and erratic rainfall with a mean annual rainfall of 796 mm with peak in July and August. Available soil water lies between 34.04 % at field capacity and 16.74 % at the permanent wilting point on a dry weight basis. The average bulk density of the soil in a depth of 0-90 cm is 1.13 g/cm^3. The dominant soil type of the center is Andosol of volcanic origin with a pH range of 7 to 8.2. The mean annual temperature was 21.2°C with a minimum of 14°C and a maximum of 28.4°C (MARC, 2020).

Description of Experimental Materials

Two tomato varieties (ARP tomato D2 and Galilea) and different good agricultural practices (mulching, compost and sticky trap) were used for the study for their advantageous in enhancing the crop performances. Bio-pesticide used for the experiment includes lecitech, trichotech, beauvittech and neem which were applied according to their labeling uniformly for all treatments. Bio-pesticides: trade name Trichtech WP active ingredient (*Trichoderma asperellum*) dose 125 g ha^{-1} and for control of soil born fungal diseases including (*Fusarium spp, Rhizoctonia spp, Sclerotinia spp* and *Phthium spp*), trade name Lechatech WP active ingredient (*Lecanicillium lecanii*) dosage 250 g ha^{-1} and control for Entomopathogenic fungus for the control of whiteflies and Trade Name Beauvitech WP active ingredient (*Beauveria bassiana*) dosage 250 g $ha^{-1}$and control for insecticide (Thrips, Whiteflies and other soft-bodied insect), Trade Name Achieve od active ingredient (*Metarhizium anisoplise*) dosage 200 ml ha^{-1} and control for spider mites. The neem extracts were used early in the sequence since they act as oviposition repellent against egg-laying female moths and a feeding deterrent against the larvae.

Treatments and Experimental Design

There were ten total treatments (2 Varieties X 5 Good Agricultural Practices levels) which were tested in the field in three replications (Table 1). The good agricultural practices used in this experiment include treatment combinations: Control (GAPs0) (without compost, mulching and stick trap), GAPs1 (Compost at 5 t ha^{-1} + mulching with 5cm thickness + yellow sticky trap), GAPs2 (Compost at 10 t ha^{-1} + mulching with 10cm thickness + yellow sticky trap + Blue sticky trap), and GAPs3 (Compost at 15 t ha^{-1} + mulching with 15cm thickness + Blue sticky traps).The experiment was laid out in a randomized complete block design (RCBD) with factorial arrangements of two factors such as varieties and Good Agricultural practices (mulching, sticky traps, and compost application (Table 1). Hence, two varieties of tomatoes (ARP Tomato D2 and Galilea) were treated with good agricultural practices along with the control (without treatments). The size of the experimental plot was $12m^2$ (4mx3m) with a net plot area of $6m^2$ (2mx3m). Seedlings were planted at the spacing of 30cmx100cm between plants and rows, respectively. One meter and 1.5m space between plots and blocks were kept for cultural practices, respectively.

Table 1. Description of treatments set up

Trt №	Tomato variety	Type of treatment
T1	ARP Tomato D2	Control (GAPs0; without compost, mulching & stick trap)
T2	ARP Tomato D2	Compost (GAPs1 at 5tha^{-1}+mulching with 5cm(4kg) thickness+YST)
T3	ARP Tomato D2	Compost (GAPs2 at 10tha^{-1} + mulching with 10cm(8kg) thickness + YST + BST)
T4	ARP Tomato D2	Compost (GAPs3 at 15tha^{-1} + mulching with 15cm(8kg) thickness + YST + BST)
T5	ARP Tomato D2	FP (compost application at two-time intervals which was prepared from farm yard manure, ash, household refuse, grass and weeds on marc and used as plant food)
T6	Galilea	Control (GAPs0; without compost, mulching & stick trap)
T7	Galilea	Compost (GAPs1 at 5tha^{-1}+mulching with 5cm(4kg) thickness+YST)
T8	Galilea	Compost (GAPs2 at 10tha^{-1} + mulching with 10cm(8kg) thickness + YST + BST)
T9	Galilea	Compost (GAPs3 at 15tha^{-1} + mulching with 15cm(8kg) thickness + YST + BST)
T10	Galilea	FP (compost application at two-time intervals which was prepared from farm yard manure, ash, household refuse, grass and weeds on marc and used as plant food)

Where; FP=Farmer practices, GAPs = Good Agricultural practice; YST =Yellow sticky trap; BST= Blue sticky trap

Experimental Procedures and Field Management

Seeds were sown on a tray medium under Green house to avoid rain water contact with the leaf of the seedling. Watering using a watering can was made just on the soil surface caring to avoid wet contact with seedling foliage. All handling was properly randomized with equal opportunity of being placed or assigned in a particular space in each block. Transplanting of seedlings to the experimental field was done at 3-5 true leaves developed when seedling become attained a height of about 15-25cm. The experimental plot was thoroughly plowed and leveled using a tractor and human labor. Ridge lines were prepared at 25 cm height from the furrow. The gross size of the plot was 12m^2 and the net plot was 6m^2. One meter walkway was used in between the plot and closure. On each experimental plot, 40 seedlings were planted at the spacing of 30cmx100cm between plants and rows, respectively. For treatment under good agricultural practice (GAPs) and farmer practices (FP); compost was made from crop residue, farm yard manure, ash, household refuse, grass and weeds on marc and used as plant food using standard procedure for compost preparation before three months (Hailu, 2010). Compost was applied to the plots before the seedling transplanted at 3kg, 6kg and 9kg per plot. Mulching with 5cm (4kg), 10cm (8kg) and

15cm (12kg) thickness of wheat straw were applied in medially after seedling transplant, sticky trap one, yellow sticky trap per plot, blue and yellow sticky cakehole per plot and one blue sticky trap per plot at 30 days interval for two round. Biopesticide application were done on GAPs treatment starting from 2nd weeks after transplanting until fruit setting phase (trichotech 2gm with 1.5 liters water, lectech 4 gm 22 liters and beuvitech 4gm with 14 litres water per plot, respectively) at seven days interval depending on the weather condition which is not contacted with any chemical. Prior to the Inflorescence initiation phase, staking was made to tomato plant life using stick and rope. Farmers' practice mainly involved calendar-based spraying of Tracer (Spinosad 45% SC), Radiant (Spinetoram 11.7% SC) and Tutan (Tutan 36% SC). Moreover, plants with the symptom of virus infection were rouged out and buried. Standard field management practice such as watering, weeding and cultivation was performed uniformly during the growing season for all planting period. Diseases (blossom end rot and powdery mildew), insects (aphid) and weeds management were monitored depending on the treatment utilized to record data. Harvesting was done by hand when the fruits become matured.

Data Collection and Measurements

In all treatments, ten plants were randomly selected from the central two rows and tagged before flowering for recording phenology and growth data measurements. Yield, yield components and quality parameters of tomatoes were considered per plot and converted to hectare bases in this study. Diseases related data were recorded throughout the plants' growth by close follow-up of the experimental field.

Crop phenology observation was made on a plot basis. Days to 50% flowering was recorded as the number of days from transplanting to the time when 50% of plants in each plot set flowers, and days to 90% maturity was recorded as the number of days from the date of transplanting to the date when 90% of fruits were reached physiologically maturity in each plot. Growth parameters like plant height was measured from the ground level to the tip of the uppermost of the main stem at 90% maturity stage by using a tape meter and taken from ten plants. The number of primary branches extending from the main stem was counted and recorded on 10 randomly selected plants at the maturity stage from each plot. Number of secondary branches extending from the primary branches was counted and recorded on 10 randomly selected plants at the maturity stage from each plot.

Yield and yield related parameters were also recorded based on their aspects. Number of fruits per plant and per cluster was recorded by counting the total number of fruit clusters per plant and number of fruits per cluster from 10 randomly selected plants from each plot at maturity. Ten fruits weight was weighed after harvest from the 10 randomly tagged plants. Fruit polar and equatorial diameter (mm) was measured by using digital caliper from five randomly selected tomato fruits per plant and their means were recorded as mean fruit polar and equatorial diameters. Marketable and unmarketable fruits weights per plant (kg) were measured as those fruits free from any defects (healthy) and having diseased, respectively from the 10 randomly tagged plants of each plot (Lemma, 2000). Then, total fruit yield per hectare (t ha^{-1}) was the addition of marketable and unmarketable fruit yield per hectare of fruit yield per net plot harvested three times was expressed in tons per hectare.

Quality attributes like pH of tomato fruit juice was determined by using a juice extractor, filtered with cheese cloth and measured with a pH Meter indicated by Acedo *et al*. (2006); number of locules per fruit were counted from 10 fruits; and total soluble solid (TSS) of fruit juice (Brix) was determined from an aliquot of juice filtered using a cheese cloth of 50ml of the slurry and measured by hand refractometer with a range of 0 to 32 ^{0}Brix and a resolution of 0.2 Brix by placing 1 to 2 drops of clear juice on the prism.

Pests (diseases and insects) that affected tomato crop was monitored and recorded throughout the whole growth of the crop. Disease incidence and severity were assessed every seven days to the maturity of tomatoes. Disease incidence refers to the proportion of plants affected by diseases; while disease severity was the relative or absolute area of plant tissue affected by the disease. The disease scoring was made by visual assessment of symptomatic leaves, petioles, fruits and stems on a scale rating of 1-4 where; 1 = 0% (no disease); 2 = < 10% (low severity); 3 = 10-50% (moderate severity) and 4 = >50% (high severity) (Maerere *et al*., 2010a). Disease incidence values were calculated using the following formula:

$$\text{Diseases incidence} = \frac{\text{Number of diseased plants}}{\text{Total plants per plot}} \times 100$$

Data Analysis

Data were subjected to analysis of variance (ANOVA) using SAS standard procedures. Least Significance Differences (LSD) at a 5% probability level was used to separate the means.

Partial Budget Analysis

The value to the farmer was partially estimated from the potential savings to the farmer of applying seeds, compost, biopesticide, sticky traps and mulching. In this experiment, only variable financial analysis was done for use as a variable for each treatment, the yield of tomato and GAPs utilized. Economic analysis should be done to calculate weather it was economically viable or not. By doing such analysis, control and GAPs were compared their profits with their costs and estimating their income. The two important points to consider when conducting economic analysis are total cost and income. Total cost payments for land preparation, labor, inputs (seed, fertilizer, mulching, compost, sticky trap, bio-pesticides, pesticide and stack), seedling and transplanting cost, field management, stacking cost, transporting cost and harvesting cost. When calculating income, the determining factors are the amount of produce harvested and the market price. All produce is calculated in monetary terms and sold to market (opportunity cost). All costs and incoming amounts were calculated and added up to reach total figures for total cost and income. The figure for total cost is subtracted from the total income to determine actual earnings (net income or profit). MRR was calculated as the ratio of change in return on the average of each replicated treatment to the change in total cost concerning the control. It compares the increments in costs and benefits between pairs of treatments. Benefit-cost ratio which found that Gross return dived by the total cost of production. With a look at the future, cleaner products resulting from the implementation of GAPS should allow better access to domestic and international markets. Domestic markets will also likely increasingly require better quality and low chemical residues in the products. According to CIMMT (1988), the minimum acceptable marginal rate of return (MRR %) should be between 50 and 100%.

RESULTS AND DISCUSSION

Response of Crop Phenology and Growth Parameters to GAPs and Variety

Days to flowering and physiological maturity

Results indicated that there were significant differences (p<0.05) on 50% flowering and 90% maturity days, plant height, number of primary and secondary branches, fruit per cluster and per plant, fruit length, fruit cluster, per plant, fruit weight and length, marketable, unmarketable and total fruits weight, number of lucolels and pH due to the effects of GAPs and variety, and some parameters were affected by the interaction of the two factors as indicated in Table 2.

Table 2. Mean square values for crop phenology, growth, yields and quality parameters as influenced by the main and interaction effects of Good Agricultural Practices (GAPs) and Variety of tomato

Parameters	Variety	GAPs	Variety x GAPs
50% Flowering date	56.03***	376.9167***	10.783**
90%Maturity date	112.13**	3687.783**	43.05**
Plant height (cm)	1520.83***	646.324167 ***	15.30283**
No of primary branches	6.44033**	19.362**	0.12033333**
No of secondary branches	34.347***	72.4878333***	0.8245**
No of fruit per cluster	0.432**	4.4813 **	0.047**
No of fruit per plant	116.03***	1148.9 ***	4.45 ns
Fruit Length	3113.04***	7827.758***	284.4553**
No of fruit cluster per plant	116.03**	1148.95**	4.45ns
Fruit weight(gm.)	6259.5***	105.10ns	123.40ns
Fruit width	4358.485***	10788.825 ***	38.61867ns
Marketable fruit Weight(Q/ha)	15248.76**	52871.0876***	411.0414ns
Unmarketable fruit Weight(Q/ha)	140.83ns	7524.71667***	1140.583**
Total Fruit Weight(Q/ha)	18221.77**	59922.8134***	655.99ns
No of Lucoles	0.0053ns	3.017167***	0.9928***
pH	2.28**	3.667***	0.5925**
TSS	2.1NS	0.027NS	0.2NS

Where, ns =non-significant, and *, **, ***, significant at P < 0.05, 0.01 and 0.001 LSD tests, respectively

The latest days to 50% flowering (40 and 41) and 90% physiological maturity (113 and 114) were recorded from ARP tomato D2 and Galilea varieties, respectively on the FP plot. While, earliest days to flowering (20 and 22) and maturity (92 and 84) was recorded from ARP tomato D2 and Galilea with GAPs3, respectively (Table 3). The early day to flowering and maturity with GAPs3 application might be due to the higher rates of GAPs compositions (compost and mulching), which initiated plant and root growth of tomato, in the early establishment of the plant immediately after transplanting and stimulated early flowering and setting of fruit. In agreement with this result, Ogbomo (2011) found that all fertilized plots with organic fertilizer flowered and matured also earlier than those not fertilized plots. Kawthar *et al*. (2010) indicated that the earlier number of days to flowering was attributed to the acceleration of the vegetative stage through the stimulating result of the absorbed food in the photosynthetic process.

Table 3. Interaction effect of Good Agricultural Practices (GAPs) and Variety on flowering and maturity of tomato crop

	Days to 50% flowering		**Days to 90% physiological maturity**	
GAPs	ARP Tomato D2	Galilea	ARP Tomato D2	Galilea
Control	38.67[ab]	37.00[bc]	109.67[b]	111.70[ab]
GAPs1	34.00[c]	28.67[d]	106.00[c]	101.00[d]
GAPs2	29.33[d]	24.00[e]	99.67[d]	89.70[e]
GAPs3	22.33[ef]	20.00[f]	92.00[e]	84.30[f]
FP	40.00[a]	41.00[a]	113.00[a]	114.30[a]
LSD (0.05)	3.24		3.14	
CV (%)	6.05		1.80	

Where; LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of variation; Means in a column followed by the same letter are not statistically different at 5% level of significance.

Plant height

Tomato plant height was significantly (P<0.01) influenced by GAPs, variety and their interaction (Table 4). Highest plant height (107.50 cm) was produced by Galilea variety with FP treatment; while, the shortest tomato height (68.63 cm) was obtained from the ARP tomato D2 variety on the control plot (Table 4). Such a higher value might be due to inadequate fertile soil, improves soil organic matter capacity and then provides required macro- and micro-nutrients for plant development (Tejada *et al*., 2009). The N produced by the organic fertilizer and inorganic plant food seems to increase the height of the plant as compared to the control (Usman *et al*., 2015). This report was in agreement with the finding of Meseret *et al.* (2012) who stated that the plant height of tomato variety ranged between 40.20 cm and 107.00 cm. Hussain *et al*. (2001) reported a wide range of differences (61.60cm - 126.50cm) in plant height among the 10 tomato genotypes evaluated in Pakistan. Similarly, Dufera (2013) obtained a wide difference (51.50-129.70 cm) for plant height in tomatoes in Ethiopian.

Table 4.Interaction effect of Good Agricultural Practices (GAPs) and Variety on plant height

	Plant height (cm)	
GAPs	ARP Tomato D2	Gelilea
Control	68.63^{g}	81.30^{e}
GAPs1	72.30^{f}	84.50^{d}
GAPs2	75.56^{f}	87.63^{d}
GAPs3	81.33^{e}	101.10^{b}
FP	93.26^{c}	107.50^{a}
LSD (0.05)	3.07	
CV (%)	2.11	

Where; LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of variation; Means in a column followed by the same letter are not statistically different at 5% level of significance.

Primary and secondary branches number

Number of primary and secondary branches showed significant difference ($p<0.01$) due to the GAPs, variety and their interaction (Table 5). The highest number of primary and secondary branches (8.6 and 16.5) were recorded from Galilea variety with FP treatment; while, the lowest (3.06 and 5.53) was obtained from ARP tomato D2 variety on the control plot (Table 5). The increased number of branches was probably due to the ability of compost to enhance plant development and initiate more number of primary and secondary branches per plant. The differences observed on the number of primary and secondary branches per plant might be due to GAPs. Optimum mulch increased vegetative development of tomato by protecting H_2O loss from soil and facilitating mineral uptake to the plant, provide favorable condition by optimizing the soil temperature, increased total nitrogen and organic matter by the compost applied, and root development stimulated by phosphorus in better usage of water and other food in the soil and promotes a sturdy development of stem and healthy leaf (Lyimo *et al*., 2015). This finding is agreed with the findings of Curtis and Claassen (2005) and Nguyen *et al*. (2011), who reported that, the positive effect of compost on plant development by increasing nutrient availability.

Table 5. Interaction effect of GAPs and variety on primary and secondary branches of tomato

	Primary branches (number)		Secondary branches (number)	
GAPs	ARP Tomato D2	Galilea	ARP Tomato D2	Galilea
Control	3.06[de]	4.06[d]	5.53[f]	7.63[e]
GAPs1	4.36[d]	5.13[c]	8.76[de]	9.86[cd]
GAPs2	5.56[c]	6.83[b]	10.83[c]	12.76[b]
GAPs3	6.80[b]	7.33[b]	12.70[b]	15.50[a]
FP	7.53[b]	8.60[a]	13.43[b]	16.50[a]
LSD (0.05)	0.761		1.22	
CV (%)	7.53		6.33	

Where; GAPs=Good Agricultural Practices; LSD (0.05)= Least Significant Difference at 5% level; CV= Coefficient of variation; Means in a column followed by the same letter are not statistically different at 5% level of significance.

Effect of GAPs and Varieties on Yield Components and Yield of Tomato

Number of fruit per cluster

The result showed that the number of fruits per cluster was significantly ($P< 0.001$) affected by the main and interaction of GAPs and variety (Table 6). The maximum number of fruit per cluster (4.56) was recorded from Galilea variety with FP treatment which was statistically at par with Galilea variety treated with GAPs3 and ARP tomato D2 variety treated with FP; but the minimum (2.23 and 2.20) was obtained from both ARP tomato D2 and Galilea varieties on the control plots (Table 6). The highest fruit number per cluster might be due to the higher amount of compost covered with thick mulch that improved soil fertility of the field and increased tomato plant fruit production. On the other side, the lowest yield obtained from the control (GAPs0) plot was due to inadequate plant nutrients. The observed difference in the production of fruit clusters was number of flowers per cluster (Mohanty and Prusti, 2001; Meseret *et al*., 2012).

Fruit polar diameter

Fruit length was significantly ($P< 0.001$) influenced by GAPs and variety as well as their interaction (Table 5). The longest fruit (215.33mm) was recorded from ARP tomato D2 variety with FP that was statistically at par with GAPs3 treatments; while the shortest (104.33mm) was obtained from Galilea variety on the control plot (Table 5). The longest fruit might be due to mulching and compost added to this plot that bears greater fruit length than the control plot which is similar with the finding of Kalibbala and Bakuneeta (2011). Hossain *et al.* (2010) also reported that the average fruit length of tomatoes was ranged from 33.5 to 51.4 mm. Similarly, Singh *et al.*

(2007) observed that mulching improved plant development, yield and yield component. The longest fruit might be also due to varieties differences in tomato; similarly, Masho *et al.* (2016) reported that the highest fruit length (80.5mm) was recorded from Mersa variety, followed by ARP tomato D2 (63.7cm), Ovalred (61.8cm) and Melka shola (61.9cm) varieties.

Table 6. Interaction effect of GAPs and variety on number of fruit per cluster and fruit length

	№ of fruit per cluster		**Fruit length(mm)**	
GAPs	ARP Tomato D2	Galilea	ARP Tomato D2	Galilea
Control	2.23^{f}	2.20^{f}	126.00^{h}	104.33^{i}
GAPs1	2.90^{e}	3.10^{de}	164.33^{f}	144.00^{g}
GAPs2	3.33^{d}	3.70^{c}	188.23^{cd}	180.11^{de}
GAPs3	3.83^{c}	4.20^{ab}	209.00^{ab}	199.67^{bc}
FP	4.20^{ab}	4.56^{a}	215.33^{a}	172.93^{ef}
LSD (0.05)	0.30		13.18	
CV (%)	5.22		4.54	

Where; GAPs= Good Agricultural Practices; LSD (0.05)= Least Significant Difference at 5% probability level; CV= Coefficient of variation. Means in a column followed by the same letter are not statistically different at 5%.

Number of fruit per plant, fruit weight and width

Fruit number per plant, fruit weight and fruit width were significantly (P<0.01) influenced by GAPs and variety; but not by their interaction (Table 7). The maximum fruit number (47), fruit weight (122.9g) and fruit width (205.3mm) were obtained from the FP plot and the lowest results (13.50, 74.37g and 99.50 mm) were obtained from the control plots, respectively (Table 7). The increased fruit number, weight and width might be due to the higher application of compost with more mulch to facilitate plant development and fruit growth through which added organic matter provided enough total food to the plant; compost improved fruit setting there by increased number and yield components of tomato per plant. Similarly, Delate *et al*. (2008) found that, fruit number was numerically greater in the fertilized plot as compared to the control plot. This agrees with the determination of Saeed and Ahmad (2009), who reported that the application of mulch resulted in significantly higher fruit yield per hectare which mainly attributed to increased uptake of available nutrients in the soil as compared to the control plot; and might be due to insufficiency of essential plant nutrient that limits plant development, efflorescence number, fruit setting and growth on the control. Also, Wodajo (2015) reported that the width of tomato fruit became increased with an increased compost and mulch rates, and decreased with decreased compost and mulch amount.

The variety might have also a significant role in fruit number, weight and width of tomatoes. The more fruit number (31.6) was obtained from Galilea variety as compared to ARP tomato D2 (27.6); but higher fruit weight (106.82 g) and fruit width (171.9 mm) was obtained from the ARP tomato D2 variety as compared to Galilea variety (Table 7). Tadele (2016) reported that the maximum number of fruits per plant was obtained with ‘Melka shola’ (75.33) followed by ‘Melka-salsa’ (64.33) and the minimum number was from ‘Fetan’ (15.0) and ‘Mira-1’ (15.67) varieties. Fruit weight is one of the important traits that were directly linked with yield (Jindal *et al.,* 2015); variety Bishola produced fruits with the heaviest weight (139.2g) followed by Eshete (130.0 g) and Marglobe (123.6 g) per plant which might be probably due to larger size of fruits per cluster (Yeshiwas *et al.,* 2017). In line with this, Shah *et al*. (2011) reported an average fruit weight (67.60g). Accordingly, Masho *et al.* (2016) reported that the variety ARP tomato D2 (120.97g) produced the highest fruit weight followed by Cochoro (100.7g) and the lowest fruit weight was scored (41.75g) by the Sirinka-1 variety.

Table 7. Fruit number per plant, fruit weight and fruit width of tomato as influenced by GAPs and varieties

Treatments	Number of fruit per plant	Fruit weight (g)	Fruit width (mm)
GAPs			
Control	13.50[e]	74.37[e]	99.50[e]
GAPs1	19.33[d]	89.68[d]	138.50[d]
GAPs2	28.83[c]	108.08[c]	164.70[c]
GAPs3	39.50[b]	116.58[b]	191.50[b]
FP	47.00[a]	122.90[a]	205.30[a]
LSD(0.05)	1.45	3.44	4.10
Variety			
ARP Tomato D2	27.60[b]	106.82[a]	171.90[a]
Galilea	31.60[a]	97.82[b]	147.80[b]
LSD(0.05)	0.92	2.17	2.60
CV (%)	3.63	2.53	1.95

Where; GAPs= Good Agricultural Practices; LSD (0.05)= Least Significant Difference at 5% level; CV = Coefficient of variation. Means in a column followed by the same letter are not statistically different at 5% level of significance.

Marketable, unmarketable and total fruit yields

Marketable and total fruit yields were significantly affected by the level of GAPs and variety, but did not affect by their interaction (Table 8). The maximum marketable yields (512.60 and 512.60 q ha^{-1}) were recorded from the plots received GAPs3 and FP, respectively; also highest unmarketable yield (82.5 q ha^{-1}) was obtained from FP. The highest total fruit yield (584.61q ha^{-1}) was recorded from plot treated with FP which is statistically at par with GAPs3 (557.16 q ha^{-1}). The lowest marketable and total fruits yields (278.5 and 342.33 qt ha^{-1}) were obtained from the control (GAPs0); but lowest unmarketable yield (44.66 q ha^{-1}) was recorded from GAPs2 (Table 8). This might be due that compost incorporated into soil provided effective nutrients and soil conditions for crop growth and yields with the highest levels of GAPs. The higher marketable fruit weight might be due to the nutrients supplied from compost applied (Abbasi *et al*., 2002). Therefore, balanced nutrient content of the organic fertilizer or composted manure and the improvement of plant health by using compost can eliminate yields reduction of tomato. Ogbomo (2011) found also a positive relationship between viability in tomato plant yield and fruit production enhancement by using organic minerals. The increase in marketable yield of mulched plot of land was probably also associated with improved microclimate both beneath, the conservation of moisture above the soil surface and great weed control. Hamid *et al.* (2012) reported that, mulch significantly had higher marketable production compared to bare soil.

Variety Galilea produced a higher marketable (440.7q ha^{-1}) and total fruit (504.04 q ha^{-1}) yield as compared to the lower yields (395.6 and 454.75 q ha^{-1}) produced from ARP tomato D2 variety (Table 8). In agreement with this, Lemma (2002) reported that the tomato variety got a mean marketable fruit yield between 72.1 to 488.0 q ha^{-1} and Selamawit *et al*. (2017) reported that the mean value of total production ranged from 334 to 457 q ha^{-1} for tomato varieties. Other researchers also reported that tomato varietal difference in yield amount; highest marketable yield (560.7 q ha^{-1}) was obtained from Melka salsa variety as compared to least yield recorded from Bishola (178.9 q ha^{-1}) variety (Getachew and Tewodros, 2019). Marketable fruit yield was significantly and positively correlated with fruit number per plant and fruit weight. Varieties with higher fruit number per plant and fruit weight gave higher marketable fruit yield (Regassa *et al*., 2016). The yield obtained from the present experiment was greater than the average (400 q ha^{-1}) potential production of Roma Vf tomato variety (MARC, 2003). Thus, good management practice of the experimental site and sufficient nutrients availability in the soil has initiated plant development and fruit production. Lyimo *et al*. (2015) also stated that mulching showed significant results on development, yield component and thus, the yield of the tomato plant. Tonfack *et al*. (2013) showed that correct soil nutrient balance is essential for healthy development, high fruit production and crop productivity and are directly associated with the allocation of nutrients in sink organs.

Table 8. Marketable, unmarketable and total fruit yield as influenced by GAPs and varieties

Treatments	Marketable yield (Q ha^{-1})	Unmarketable yield (Q ha^{-1})	Total Fruit Yield (Q ha^{-1})
GAPs			
Control	278.50^{d}	63.83^{b}	342.33^{d}
GAPs1	369.20^{c}	48.50^{bc}	417.77^{c}
GAPs2	466.20^{ab}	44.66^{d}	495.11^{b}
GAPs3	512.60^{a}	45.66^{cd}	557.16^{a}
FP	512.60^{a}	82.50^{a}	584.61^{a}
LSD(0.05)	47.69	17.60	33.56
Variety			
ARP Tomato D2	395.60^{b}	59.00^{a}	454.75^{b}
Galilea	440.70^{a}	63.40^{a}	504.04^{a}
LSD(0.05)	30.16	ns	21.22
CV (%)	8.57	21.62	5.26

Where; LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of variation; ns = non-significant difference. Means in a column followed by the same letter are not statistically different at 5% level of significance.

Effects of GAPs and Varieties on Tomato Quality Parameters

Number of locules per fruit and pH value

The analysis of variance showed that the number of locules per fruit was significantly ($P < 0.01$) affected by the interaction of GAPs and variety (Table 9). The largest number of locules per fruit (4.73) was obtained from ARP tomato D2 variety with GAPs3 which was statistically at par with Galilea variety on FP and Gaps3 treatments. However, the smallest number of locules per fruit (2.90 and 2.60) was obtained from both varieties (ARP tomato D2 and Galilea) on the control plots, respectively (Table 8). The number of locules per fruit might be due to the level of compost and mulches applied.

The result of fruit pH value displayed a significant ($p<0.01$) difference due to GAPs and varieties and their interaction (Table 9). Highest pH values (4.88 and 4.60) were obtained from ARP tomato D2 and Galilea varieties with GAPs3 applied, respectively; while the lowest pH value (2.13) was recorded from Galilea variety on FP treated plot (Table 9). The variations in pH scale of tomato varieties might be due to mulching and compost level. Morra (2019) reported that the pH scale was significantly higher in bare soil than in mulched one. Ghorbani *et al*. (2008) also stated that organic fertilizer amendment showed a significant impact on post-harvest quality of tomato plants.

Table 9. Interaction effect of GAPs and variety on quality parameters of tomato

	Number of locules per fruit		**pH value**	
GAPs	**ARP Tomato D2**	**Galilea**	**ARP Tomato D2**	**Galilea**
Control	2.90^{fg}	2.60^{g}	3.20^{ef}	3.03^{f}
GAPs1	3.70^{d}	3.16^{ef}	3.73^{d}	3.57^{de}
GAPs2	4.20^{bc}	3.93^{cd}	4.30^{bc}	3.97^{cd}
GAPs3	4.73^{a}	4.50^{ab}	4.88^{a}	4.60^{ab}
FP	3.26^{e}	4.73^{a}	3.77^{d}	2.13^{g}
LSD (0.05)	0.36		0.45	
CV (%)	5.66		7.04	

Where; GAPs= Good Agricultural Practices; LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of variation. Means in a column followed by the same letter are not statistically different at 5% level of significance.

Total soluble solid (Brix)

Total soluble solid (TSS) was significantly influenced due to only various levels of GAPs applied, but a non-significant difference was recognized due to the effect of variety and their interaction (Table 10). The higher TSSs (4.82) were obtained from GAPs3 which was statistically at par with GAPs2 and FP. However, the lower TSS was recorded from the control treatment which is statistically par with GAPs1 (Table 10). These might be due to the amount of good agricultural practices applied to the crop; the higher amount of GAPs applied to the crop gave fruits with more total soluble solids indicating more level of compost and more thickness of mulches applied produced significant tomato fruit TSS.

Table 10. Total soluble solids of tomato fruit as influenced by GAPs and variety

Treatments	TSS (Brix)
GAPs	
Control	3.43^{b}
GAPs1	3.58^{b}
GAPs2	4.38^{a}
GAPs3	4.82^{a}
FP	4.47^{a}
LSD(0.05)	0.70
Variety	
ARP Tomato D2	4.11^{a}
Galilea	4.17^{a}
LSD(0.05)	ns
CV (%)	12.79

Where; GAPs= Good Agricultural Practices; LSD = Least Significant Difference; CV = Coefficient of variation; ns = non- significant different.

Effects of GAPs and Varieties on Pests Control

The number of tomato fruits severely affected by pests (insects and diseases) was recorded during all developmental stages. Insect pest damage was different among all treatments (Table 11). The number of fruits per plot bored (damaged) by insect was counted, and the highest score (1.82% per plot) was observed on ARP tomato D2 variety with FP treatment, and the lowest fruit damaged (0.68 % per plot) was counted on ARP tomato D2 variety with GAPs3. Similarly, the highest number of fruit per plot was damaged by insect pests from the Galilea tomato variety on both FP and the control (1.22% and 0.94% per plot). The lowest fruits damaged (0.68% and 0.55% per plot) was counted from both varieties (ARP tomato D2 and Galilea) with GAPs3. Hence, applications of GAPs2 and GAPs3 were significantly reduced the number of insects damage on both varieties. Dobson *et al*. (2002) reported that insects were the most destructive pests of tomato plant, causing production losses as high as 70% due to fruit boring. Also tomato leaf miner, *Tuta absoluta* was recorded in the Ambo University campus, Ethiopia for the first time in the glasshouse and open field.

Early blight and late blight diseases were observed during the experimental period; the recorded data displayed variations among all the treatments. There were considerably more early blight and late blight-affected fruits of ‘ARP tomato D2 and Galilea’ varieties with FP, GAPs1 and control plots (Table 11). In general, the visual observation of diseases occurrence on ARP tomato D2 and

Galilea varieties treated with GAPs1, FP and control tratments were showed significantly affected by the diseases (1.00, 1.71 and 1.20% per plot) and (0.98, 1.32 and 1.11% per plot), respectively. The more amount of compost and thick mulch applied along with Yellow plus Blue sticky traps utilized brought fewer diseases occurrences on both varieties of tomato fruits. Diseases in the high N-containing organic amendment had effectively controlled soil-borne plant pathogens and plant parasitic nematodes (Lazarovits *et al*., 1999).

Table 11. Number of fruits infested by insects and diseases under open field conditions treated with Good Agricultural Practices (GAPs)

Treatment	Number of fruit infested by insects in percent	Number of fruit infested by diseases in percent
ARP tomato D2 + Control	1.10	1.20
ARP tomato D2 + GAP1	0.98	1.00
ARP tomato D2 + GAP2	0.76	0.84
ARP tomato D2 + GAP3	0.68	0.89
ARP tomato D2 + FP	1.82	1.71
Galilea + Control	0.94	1.11
Galilea + GAP1	0.87	0.98
Galilea + GAP2	0.65	0.54
Galilea + GAP3	0.55	0.34
Galilea + FP	1.22	1.32

Partial Budget Analysis

The profitability analysis of this study showed a positive relationship between fruit production enhancement and viability in tomato yield using good agricultural practices. The greatest net income and total revenue (257,481 and 410,080 Eth Birr) were obtained from both varieties applied with GAPs3, and lowest net income and total revenue (129,345 and 222,800 Eth Birr) were from both varieties on the control plots (Table 11). The net income and benefit-to-cost ratio showed also a positive relation to the marketable yield produced and total revenue; maximum and minimum benefit-to-cost ratio (2.7 and 2.4) were obtained from ARP tomato D2 and Galilea varieties with GAPs3 treated and control, respectively (Table 11). GAPs3 treatment is more profitable than any other treatment given the highest benefit-cost ratio which has a higher marketable yield. The study indicated that MRR was found much greater than 100%; application of GAPs1, GAPs2 and GAPs3 significantly improved the net income and MRR of both varieties. Significantly highest MRR (424.8%) was resulted from both tomato varieties treated with GAPs3.

Similarly, Ogbomo (2011) found that application of organic fertilizers is the most effective for the optimum production and profitability of tomato crop.

Table 11. Partial budget analysis for tomato production due to the effect of GAPs & variety

Treatment	Yield	Total revenue	Total cost	Net income	Raised income	Raised cost	B:C	MRR %
ARP tomato D2 + Control	27850	222800	93455	129345	0	0	2.4	0
ARP tomato D2 + GAPs1	36920	295360	120080	175280	45935	26625	2.5	172.5
ARP tomato D2 + GAPs2	46620	372960	145527	227433	52153	25447	2.6	204.9
ARP tomato D2 + GAPs3	51260	410080	152599	257481	30048	7072	2.7	424.8
ARP tomato D2 + FP	51260	410080	168140	241940	-15541	15541	2.7	-100
Galilea+ Control	27850	222800	93455	129345	0	0	2.4	0
Galilea+ GAPs1	36920	295360	120080	175280	45935	26625	2.5	172.5
Galilea+ GAPs2	46620	372960	145527	227433	52153	25447	2.6	204.9
Galilea+ GAPs3	51260	410080	152599	257481	30048	7072	2.7	424.8
Galilea+ FP	51260	410080	168140	241940	-15541	15541	2.4	-100

Where; B:C= Benefit to Cost ratio; MRR (%) = Marginal Rate of Return (%)

CONCLUSION

Production of tomato varieties using good agricultural practices had significant influence on growth, yields and pests control. The total maximum tomato fruit yield (584.6 and 557.16 qha^{-1}) produced due to FP and GAPs3 applied were significantly improved by 70.77% and 62.76%, respectively as compared to the lowest fruit yield (342.33 qha^{-1}) produced on the control (GAPs0). Also, variety Galilea (440.70 and 504.04 qt ha^{-1}) has significantly improved marketable and total yields by 11.40% and 10.84% as compared to ARP tomato D2 variety (395.6 and 454.75 qt ha^{-1}), respectively. The greatest net income (257,481 Eth Birr) and benefit-to-cost ratio (2.7) along with better MRR (424.8%) was also obtained from both varieties with the application of GAPs3. Thus, from the study results, it is possible to conclude that the application of GAPs3 to tomato varieties significantly improved the production and productivity of tomato crops in the study area; and also Galilea variety is more productive as compared to the variety ARP tomato D2 in the study area.

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