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RESEARCH PAPER

Effectiveness of Fructón Fertilizer on Growth, Yield, and Quality of Tomato (*Solanum lycopersicum* L.) at West Shewa, Ethiopia

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Abstract

This study aims to investigate the impact of using a combination of Fructón, a bio-stimulant fertilizer, with inorganic nitrogen and phosphorus fertilizers on tomato crop performance. The experiment was conducted from October 2019 to March 2020 under irrigation in the field at two locations in the west Shewa zone: Toke Kutaye and Ilu Gelan districts. There were four treatments in the study: organic Fructón, inorganic nitrogen, and phosphorus fertilizers; a combination of Fructón and nitrogen and phosphorus fertilizers; and control plots that received no fertilization. Each treatment was replicated three times in a randomized, complete block design. Results revealed that integrated application of organic Fructón (50 g L^{-1} ha^{-1}) with inorganic nitrogen (80 kg N ha^{-1}) and P (90 kg P_2O_5 ha^{-1}) fertilizers significantly improved the growth, yield, and quality of tomato fruits. The combination treatment resulted in the highest plant height, number of primary and secondary branches, number of fruits per plant, marketability, and total yield at both Toke-Kutaye and Ilu-Gelan locations. Conversely, the untreated plot exhibits the lowest results. Additionally, supplemental application of organic Fructón with conventional nitrogen and phosphorus fertilizers enhanced the total soluble solids, pH, and titratable acidity of the tomatoes. These findings suggest the combination of organic fructón with inorganic nitrogen and phosphorus fertilizers holds promise for improving tomato growth and yield performances.

Keywords: *Fructón*, Tomato, Bio-stimulant, Fertilizer

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important, nutritious, and extensively grown vegetables in the world (Dragan *et al*., 2010; Gharezi *et al*., 2012). It is an integral part of the human diet and is popularly used in a variety of dishes, such as salad, and in cooked or processed products more than any other vegetable (Awas *et al.,* 2010; Mujtaba and Masud, 2014). Matured tomato fruits are used to prepare puree, paste, tomato powder, ketchup, sauce, and soup, whereas the unripe ones are used for preserves (Pinheiro *et al*., 2013). Tomato fruits are rich in bioactive phytochemicals such as vitamins, minerals, lycopene, carotenoids, sugar, essential amino acids, and other dietary fibers (Gupta *et al*., 2011; Gharezi *et al.,* 2012). The phytochemicals found in tomato fruit are thought to reduce the risk of human ailments (Canene-Adams *et al.,* 2005). As a result, consuming tomatoes is considered a functional food that is used to reduce the risk of malignant diseases like cancer, cataracts, heart diseases, diabetes, hyperglycemia, inflammation, arthritis, immune system decline, and brain dysfunction (Tan *et al.,* 2013; Mujtaba and Masud, 2014). Subsequently, the use of tomato in every diet is so extensive that it is almost impossible to separate it from the menus of fast-food and pizza parlors (Silva *et al.,* 2008; Tan *et al.,* 2013).

In Ethiopia, tomato is considered as a cash-generating crop for small-holder and medium-scale commercial farmers (Teka, 2013). Many farmers are interested in tomato production for its multiple harvests, high profitability, and potential to improve the revenue and nutrition of households (Awas *et al.,* 2010). Despite the tremendous benefits of the crop, the overall yield and quality of tomatoes in Ethiopia are very low compared to the regional and global average yield (Gemachu and Beyene, 2019). According to FAO (2018), the productivity of tomatoes in Ethiopia was 6.18 tons ha-1, which is by far very low when compared to the average productivity of the world (38.27 tons ha^{-1}), Africa (16.08 tons ha-1), and East Africa (14.45 tons ha-1), respectively.

The main reasons for low production and productivity of tomatoes in Ethiopia are inappropriate agronomic practices such as poor fertilization, inappropriate spacing, pests, diseases, and a lack of improved varieties (Aseffa, 2013). Inappropriate fertilization and the indiscriminate use of chemical fertilizers are the major factors that cause low crop productivity in Ethiopia (Balemi, 2015). Omidire *et al.* (2015) reported that the exclusive use of inorganic fertilizer can affect soil properties and negatively affect soil productivity. Balemi (2015) also stated that indiscriminate use of chemical fertilizers alone can result in the depletion of essential micronutrients, thereby resulting in an overall reduction in total productivity. Due to the soil fertility depletion from the exclusive use of inorganic fertilizers, along with the reality of their negative impact on the environment, the combined application of organic and inorganic fertilizer sources is becoming a suitable nutrient management practice (Omidire *et al.,* 2015).

Several investigators reported that a long-term and sustainable crop production system could be achieved through the integration of inorganic and organic sources of nutrients (Graham *et al.,* 2017; Saha *et al.,* 2017; Biramo, 2018). To maintain the sustainability of crop production, it is advisable to choose a production system that has a less harmful effect on the environment while helping to achieve optimum yields and quality produce (Gomes *et al.,* 2017). *Fructón* fertilizer is a newly produced organic fertilizer used to improve vegetable yield and quality. It is water-soluble and the product of the kimetic group, which contains micro-elements such as boron and molybdenum in addition to nitrogen and potassium. It is an excellent bio-stimulant fertilizer that is used to increase the fruit size and to avoid flower drops and fruit cracking in fruit vegetables. However, the efficacy of integrated application of *Fructón* with inorganic nitrogen and phosphorus fertilizer sources has not been evaluated on the production and quality of tomatoes yet. Keeping this in view, the present research was aimed to evaluate the effectiveness of integrated organic *Fructón* fertilizer and inorganic nitrogen and phosphorus fertilizers on the growth, yield, and quality of tomato fruits at the West Shewa zone, Oromia region, Ethiopia.

Materials and methods

Description of Study Areas

The field trials were conducted at two locations in the west Shewa zone: Toke Kutaye and Ilu Gelan districts, from October 2019 to March 2020, under irrigation. Toke Kutaye district is located at 8º58' to 8.97º N latitude and 37º 46' to 38º E longitude, and Ilu Gelan district is located at 8º49' to 9º5.3' N latitude and 37º 31.3' E longitude. The experiment in the Toke Kutaye district was conducted at Ambo University, a horticulture experimental field located in Guder. For the Ilu Gelan district, a farmer's field was used for the trial. The altitudes of the experimental sites in Toke Kutaye and Ilu Gelan districts were 1800 and 1812 meters above sea level, respectively. Both study areas have a unimodal rainfall pattern (Balemi, 2015; Tadesse et al., 2018). The soil texture of Toke Kutaye's experimental site was clay with 21% sand, 26% silt, and 53% clay with a pH (1:2.5 - H_2O) of 5.96, and that of the Ilu-Gelan soil was also clay with 27% sand, 24% silt, and 49% clay with a pH (1:2.5 - H_2O) of 5.63.

Experimental design and treatments

The experiment consisted of four treatments: organic nitrogen (N) and phosphorus (P) fertilizers, *Fructón* fertilizer, a combination of organic nitrogen and phosphorus and organic *Fructón* fertilizers, and a control (no fertilizer applied). The treatments were replicated three times and laid out on experimental units using a randomized complete block design (RCBD). For the inorganic nitrogen and phosphorus fertilization, the recommended rates (80 kg of N ha-1 and 90 kg of P2O5 ha-1) were used. For the *Fructón* receiving plots, organic *Fructón* at the rate of 50 g L-1 ha-1 was applied four times at different stages of growth. The sources of inorganic fertilizers used for nitrogen and phosphorus were UREA (46.0.0) and DAP (18.46.0), respectively. For the inorganic fertilizer-receiving plots, DAP was applied at transplanting and urea was applied at the flower initiation stage. Details about the treatments set up for this study and the nutrient contents of *Fructón* were shown in Table 1 and 2, respectively.

Table 1. Details of fertilizer treatments used in the study.

Treatment code	**Treatments details**
TF0	Control (no fertilization)
TF1	Inorganic nitrogen and phosphorus fertilizers at the rate of 80 Kg N ha^{-1} and 90 Kg of P_2O_5 ha^{-1}
TF2	*Fructón* at the rate 50 g L^{-1} ha^{-1} applied four times at every 15 days after 1st flower appearance
TF3	Combination of inorganic nitrogen and phosphorus fertilizers at a rate of 80 Kg N ha^{-1} and 90 Kg of P_2O_5 ha^{-1} in combination with *Fructón* at a rate of 50 g L^{-1} ha^{-1} applied four times every 15 days after 1st flower appearance

Table 2. Nutrient contents of *Fructón* used for the Study.

Composition	**%W/W**
Nitrogen (N)	1.5
Potassium (K_2O)	5.0
Boron (B)	13.5
Molybdenum (Mo)	5.0

Source: (Ficha, 2017)

Experimental Procedures and Crop Management

The seed of the Roma VF tomato variety was drilled on a 1.5 m x 4 m-sized seedbed at the Ambo University Guder campus experimental site on October 24, 2019. The experimental fields were cleared, ploughed, harrowed, and prepared to a fine tilt. Then the experimental areas were divided into small homogenous blocks, to which a complete set of treatments were assigned randomly. Transplanting of seedlings on the experimental fields was done at the 3–5 true leave stage. The seedlings were planted at a spacing of 90 x 40 cm between rows and between plants, respectively. Watering was done using furrow irrigation. Inorganic fertilizer, phosphorus, and nitrogen were applied to the experimental field following the recommended rate of 90 kg P_2O_5 ha^{-1} and 80 kg N ha^{-1} in the form of diammonium phosphate (DAP) and urea, respectively. *Fructón* was applied every 15 days using the foliar application method after the first flower appearance. All agronomic practice has done as per recommendation uniformly to all plots except for fertilization.

Data collection

Growth, yield, and quality data of tomatoes were recorded from five randomly selected tomato plants in the central rows of each plot, and the mean value was used for analysis. Growth parameters: plant height (cm) measured from the ground to the tip apex of the tomato plant at maturity stage. Primary branches and the number of secondary branches were counted and recorded at the maturity stage.

Yield and yield-related parameters: number of clusters per plant, average number of fruits per cluster, and marketable and unmarketable yields (tons ha-1) were collected. The number of clusters was counted at 50% flowering. Marketable and unmarketable yields (tons ha^{-1}) were measured according to the method prescribed by Zeleke and Derso (2015) by considering diseased, infected fruit insect pests, physiologically, and mechanically damaged fruits as unmarketable, while fruits free from any visible damages as marketable. Marketable and unmarketable fruits obtained from each net plot area were weighed with an analytical balance in kilograms and converted into hectares. Total fruit yield (tons ha^{-1}) was obtained by adding marketable and unmarketable fruit yields. Fruit diameters were measured from three randomly selected sample fruits from the selected plant using digital calipers, and the mean value was calculated for the analysis.

Quality parameters: total soluble solids, pH, and titrable acidity of tomato juice were determined and analyzed. For the quality analysis, two tomato fruits from each selected plant were taken and sliced. An aliquot of clear juice was prepared using a juice extractor (Model: 31JE35, USA) and used for all chemical analysis. The pH value of tomato juice was measured using a pH meter (model: ME962, Max Electronics, India). Total soluble solids (TSS in °Brix) were determined based on the methods described by Tsegay *et al.* (2013). A digital Palm Abbe Refractometer (Model: #PA201, MISCO®, Virginia) with a lower range (0 to 32 °Brix) and resolutions of 0.2 °Brix was used to determine it by placing a few drops of clear juice on the prism of the refractometer. The titratable acidity (TA) of tomato pulp was determined according to the method prescribed by Moneruzzaman *et al.* (2009). Ten milliliters of tomato pulp were taken from the prepared juice and diluted with 30 ml of distilled water. The diluted juice was filtered through cheesecloth, and 10 ml of filtrated tomato juice was poured into the conical flask. Then, two drops of 1% phenolphthalein indicator were added, and the flask was shaken vigorously. A 50-ml burette was filled with 0.1N NaOH solutions, and the solution was titrated into a conical flask while keeping the flask shaking till a permanent pink color appeared. The volume of NaOH solution used for titration was recorded, and the percentage titratable acidity was calculated using the following formula: $\text{TA}\ (\%) = \frac{T\ X\ N\ X\ V1\ X\ E}{V2\ X\ Wt\ X\ 1000}\ X\ 100$, where: T: Titre, N: normality of NaOH, V1: volume made up, E: mill equivalent wt. of acid, *i.e.*, citric acid in tomato = 0.06404, V2: volume of extract, and Wt: the weight of the sample. A total soluble solid-to-acid ratio was calculated by dividing the value of TSS (°Brix) by the value of the percentage of titratable acidity.

Statistical data analysis

The collected data were subjected to statistical analysis using Genstat 16th edition software. The statistical significance of the hypotheses was assumed when the P-value was less than 0.05.

Results and discussions

Plant height (cm), number of primary and secondary branches per plant

Analysis of variance revealed that the growth parameters of tomatoes, including plant height, number of primary branches, and number of secondary branches per plant, were significantly affected by the type of fertilizer used (Table 3).

Table 3. Effect of integrated application of Fructón and NP (nitrogen and phosphorus) fertilizers on growth parameters of tomato plant

Location	Treatments	Plant Height (cm)	Number of Primary Branches	Number of Secondary Branches
Toke Kutaye	Control	49.89^{c}	2.78^{c}	5.11^{c}
	Inorganic nitrogen and phosphorus fertilizers	56.89^{b}	3.11^{b}	6.45^{b}
	Organic *Fructón* fertilizer	61.22^{b}	3.22^{b}	6.56^{b}
	Organic *Fructón* plus inorganic nitrogen and phosphorus fertilizers	70.44^{a}	4.33^{a}	9.00^{a}
	LSD	5.692	0.246	1.009
	CV (%)	4.8	3.7	7.5
Ilu Gelan	Control	49.33^{c}	2.22^{c}	4.11^{c}
	Inorganic nitrogen and phosphorus fertilizers	55.00^{bc}	2.56^{bc}	5.44^{b}
	Organic *Fructón* fertilizer	56.00^{b}	2.89^{b}	5.56^{b}
	Organic *Fructón* plus inorganic nitrogen and phosphorus fertilizers	65.11^{a}	3.67^{a}	7.89^{a}
	LSD	6.35	0.43	0.91
	CV (%)	5.6	7.6	7.9

Means with the same letters in a column are not significantly different at 5% level of significance according to Duncan's Multiple Range test (DMRT); LSD: Least Significant Difference, CV: coefficient of variance

The combined application of organic *Fructón* with conventional nitrogen and phosphorus fertilizers significantly improved the plant height of tomatoes ($P < 0.05$). The tallest plant heights (70.44 cm) in Toke Kutaye and (65.11 cm) in Ilu Gelan were recorded from plots applied with a combined application of *Fructón* (50 g L^{-1} ha^{-1}) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1}), whereas the shortest plant height was obtained from the control plot at both locations. This finding is consistent with previous studies that have reported the application of mixed organic and inorganic fertilizers resulting in taller tomato plants (Islam *et al.,* 2017). The increase in plant height can be attributed to balanced nutrition, improved nutrient uptake, and increased carbohydrate synthesis (Omidire *et al.,* 2015).

Similarly, the number of primary branches per plant of tomato was significantly ($P < 0.05$) influenced by the types of fertilizers used. The highest number of primary branches was observed in the plots treated with the combination of *Fructón* and inorganic fertilizers, while the lowest number was in the control plot. Furthermore, the highest number of secondary branches per plant was observed in the treatment with the combination of *Fructón* and inorganic fertilizers, while the lowest number was in the control treatment. The result aligns with previous studies that have shown integrated application of organic and inorganic fertilizers leading to a higher number of primary branches per plant (Meaza *et al*., 2007; Ogundare *et al.,* 2015; Jat *et al.,* 2018). According to Meaza *et al. (*2007), the integrated application of organic ComCat® and inorganic nitrogen and phosphorus fertilizer resulted in a significantly higher number of primary lateral branches per plant compared to tomato plants applied with ComCat® and control treatments. The increase in primary and secondary branches can be attributed to the influx of nitrogen and phosphorus from both organic and inorganic sources.

Fruit cluster per plant, number of fruits per cluster, and number of fruits per plant

The number of fruit clusters per plant, the number of fruits per cluster, and the number of fruits per plant were all significantly ($P < 0.05$) affected by fertilizer types at both locations in Toke Kutaye and Ilu Gelan districts, as depicted in Table 4. The maximum number of fruit clusters per plant (21.00 in Toke Kutaye and 20.11 in Ilu Gelan) was obtained from plots treated with a combination of *Fructón* and inorganic nitrogen and phosphorus fertilizers. On the other hand, the minimum number of fruit clusters per plant (14.56 in Toke Kutaye and 14.22 in Ilu Gelan) was counted in the control plots. The result of this study coincides with the findings of Islam et al. (2017) who obtained a higher number of fruit clusters per plant from the combined application of organic and inorganic fertilizer compared to the sole application of organic or inorganic and control treatments.

The number of fruits per cluster was significantly affected by the combined use of organic *Fructón* and inorganic nitrogen and phosphorus fertilizers ($p < 0.05$). Plants treated with *Fructón* alone also produced a higher number of fruits per cluster, although not significantly better than those treated with recommended rates of inorganic fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1). This complementary application of organic and inorganic fertilizers resulted in a higher number of fruits per cluster, which might be due to a reduction in the number of aborted fruits.

Furthermore, the combined application of *Fructón* and inorganic nitrogen and phosphorus fertilizers significantly increased the number of tomato fruits per plant at both the Toke Kutaye and Ilu Gelan experimental sites. In Toke Kutaye, the combination treatment increased the number of fruits per plant by 30.1% and 47.8% compared to the use of inorganic fertilizers alone and the control group, respectively. Similarly, at Ilu Gelan, the combination treatment increased the number of fruits per plant by 25.6% and 44.3% compared to the use of inorganic fertilizers alone and the control group, respectively. The control group had the lowest number of fruits per plant at both locations. The result of this study is in line with the findings of Yeptho et al. (2012), who reported that integrated application of 50 percent NPK, 50 percent poultry manure, and biofertilizer resulted in a higher number of fruits per plant over the other treatments in tomatoes. Ogundare et al. (2015) also revealed that the combined use of 125 kg ha-1 NPK and 3 tons ha-1 poultry waste produced the highest number of tomato fruits per plant compared to the use of inorganic NPK fertilizer alone or control treatments. The improved yield parameters of tomatoes from combined application could be attributed to the bio-stimulant activity of *Fructón* in accelerating flower bud formation.

Table 2. Effect of integrated application of *Fructón* and NP fertilizers on the number of fruit clusters per plant, fruits per cluster, and fruits per plant of the tomato plant

Location	Treatments	Number of fruit cluster per plant	Number of fruits per cluster	Number of fruits per plant
Toke Kutaye	Control	14.56^{c}	2.04^{c}	29.67^{c}
	Inorganic nitrogen and phosphorus fertilizers	16.67^{b}	2.40^{b}	39.78^{b}
	Fructón Fertilizer	17.22^{b}	2.41^{b}	41.33^{b}
	Fructón + inorganic N and P fertilizers	21.00^{a}	2.72^{a}	56.89^{a}
	LSD	1.443	0.250	6.354
	CV (%)	5.6	5.2	7.6
Ilu Gelan	Control	14.22^{c}	2.02^{b}	28.78^{c}
	Inorganic Fertilizers	16.00^{b}	2.41^{a}	38.44^{b}
	Fructón Fertilizer alone	16.22^{b}	2.55^{a}	41.22^{b}
	Fructón + inorganic N and P fertilizers	20.11^{a}	2.58^{a}	51.67^{a}
	LSD	0.596	0.308	5.277
	CV (%)	1.8	6.4	6.6

Means with the same letters in a column are not significantly different at 5% level of significance according to DMRT; LSD: least significant difference, CV: coefficient of variance.

Marketable, unmarketable and total yield

The total yield, marketable yield, and unmarketable yield of tomatoes were significantly affected by the combined use of *Fructón* and inorganic fertilizer ($p < 0.05$). The highest total yield of tomato (46.20 tons ha-1) in Toke Kutaye and (39.40 tons ha-1) in Ilu Gelan, respectively, was obtained from plots applied with Fructón + inorganic nitrogen and phosphorus fertilizers, followed by plots applied with Fructón alone (Table 5). The

combined application of *Fructón* with inorganic nitrogen and phosphorus fertilizers significantly increased the total yield of tomato fruits compared to other treatments. The minimum yield was obtained from the control plots. Combined application of *Fructón* with inorganic nitrogen and phosphorus fertilizers at Toke Kutaye significantly increased the total yield of tomato fruits by 22.2%, 30.3%, and 43.3% compared to plots applied with *Fructón*, inorganic nitrogen and phosphorus fertilizers, and the control plot, respectively. A similar trend was also observed at Ilu Gelan, where the mixed application of *Fructón* with inorganic nitrogen and phosphorus fertilizers significantly increased the number of tomato fruits per plant by 25.4%, 39.6%, and 53.8% compared to plots applied with sole *Fructón*, inorganic nitrogen and phosphorus fertilizers, and the control treatment, respectively.

Table 5. Effect of integrated application of *Fructón* and NP fertilizers on the marketable, unmarketable, and total yield of tomato plants

Location	Treatments	Marketable Yield (tons ha^{-1})	Unmarketable yield (tons ha^{-1})	Total Yield (tons ha^{-1})
Toke Kutaye	Control	18.20^{c}	8.40^{b}	26.20^{c}
	Inorganic N and P fertilizers	26.13^{b}	6.07^{ab}	32.20^{b}
	Fructón Fertilizer alone	30.33^{b}	6.60^{ab}	35.93^{b}
	Fructón + Inorganic N and P fertilizers	42.47^{a}	3.73^{a}	46.20^{a}
	LSD	4.822	2.985	5.594
	CV (%)	8.2	25.1	7.9
Ilu Gelan	Control	9..33^{d}	8.87^{c}	18.20^{d}
	Inorganic N and P fertilizers	17.27^{c}	6.53^{b}	23.80^{c}
	Fructón Fertilizer alone	23.80^{b}	5.60^{b}	29.40^{b}
	Fructón + Inorganic N and P fertilizers	35.93^{a}	3.27^{a}	39.40^{a}
	LSD	2.510	1.922	1.805
	CV (%)	5.8	15.9	3.3

Means with the same letters in a column are not significantly different at a 5% level of significance according to DMRT; LSD: Least Significant Difference, CV: coefficient of variance

The result of this study coincides with the findings of Ogundare et al. (2015), who obtained the highest total yield of tomato plants applied with 124 kg ha-1 NPK fertilizer and 3 tons ha-1 poultry manure. Besides, this result agrees with the finding of Islam et al. (2017), who reported that mixed fertilizer (2/3 organic vermicompost + 1/3 inorganic NPK fertilizers) resulted in the highest number of fruits per plant compared to sole application organic vermicompost and inorganic NPK fertilizers. Furthermore, the result coincides with the findings of Jat et al. (2018), who reported that the integration of organic manures with inorganic fertilizers improves the overall plant growth, yield, and soil macronutrient status more than the sole application of either of these nutrients.

The marketable yield of tomato fruits also varied significantly due to the integrated application of nutrients. The highest marketable yield (42.47 tons ha-1 and 35.93 tons ha-1) in Toke Kutaye and Ilu Gelan, respectively, was obtained from plots applied with a combination of *Fructón* and inorganic nitrogen and phosphorus fertilizers. The minimum marketable yield at both experimental sites was obtained from a plot that received no fertilizer (control). This result is in line with previous studies (Pandey and Chandra 2018) that have shown the positive effects of integrated nutrient application on marketable yield. The increase in total and marketable yield can be attributed to the additive effect of each fertilizer as well as the enhanced translocation of carbohydrates towards fruit formation. The frequent foliar application of *Fructón* may have also contributed to the overall increase in yield. On the other hand, the combined application of *Fructón* and inorganic nitrogen and phosphorus fertilizers significantly reduced the unmarketable yield of tomatoes. This result is consistent with previous studies that have observed a reduction in unmarketable yield with the use of integrated organic fertilizers. The reduction in unmarketable yield can be attributed to the foliar application of *Fructón*, which enhances the concentration of trace elements and accelerates fruit formation. On the other hand, the combined application of *Fructón* (50 g L-1 ha-1) and inorganic nitrogen and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers significantly reduced the unmarketable yield of tomato at both experimental sites. The result of this study agrees with the findings of Yanar et al. (2011), who observed a reduction in unmarketable yield in tomato plants applied with integrated organic fertilizers.

Quality parameters

The variability of tomato fruit quality parameters in response to applied fertilizer types is presented in Table 6. The fruit diameter, pH, total soluble solids (TSS), and titrable acidity (TA) were significantly ($P < 0.05$) affected by the sole and integrated use of inorganic nitrogen and phosphorus fertilizers and organic sources. The largest fruit size of tomato (52.07 mm) in Toke Kutaye and (51.73 mm) in Ilu Gelan were obtained from tomato fruits harvested from plots applied with *Fructón* (50 g L-1 ha-1) + chemical nitrogen and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers. At both experimental sites, the smallest fruit sizes (40.77 mm) and (40.37 mm) of tomato fruits in Toke Kutaye and Ilu Gelan, respectively, were obtained from plots that received no fertilizer (control). Several investigators have also reported similar findings in terms of fruit length, fruit diameter, and fruit volume due to integrated nutrient management (Kochakinezhad et al., 2012; Ilupeju et al., 2015; Saha et al., 2017). The increment in fruit diameter of tomato fruits harvested from plots applied with a combination of *Fructón* and mineral nitrogen and phosphorus fertilizers could be attributed to the additive effect of each fertilizer, which enhanced the translocation of carbohydrates and water absorption toward fruit and resulted in increased turgor pressure and larger tomato fruit.

Table 6. Effect of sole and integrated use of inorganic nitrogen and phosphorus fertilizers and organic *Fructón* fertilizer on quality parameters of tomato fruits

Location	Treatments	FD (mm)	pH	TSS (°Brix)	TA (%)	TSS/TA ratio
Toke Kutaye	Control	40.77^{d}	4.50^{c}	4.23^{c}	0.16^{c}	26.67^{c}
	Inorganic N and P fertilizers	44.83^{c}	4.30^{b*}	4.40^{b}	0.28^{b}	15.70^{b}
	Fructón fertilizer alone	48.03^{b}	4.37^{b}	4.43^{b}	0.31^{b}	14.20^{ab}
	Fructón + Inorganic N and P fertilizers	52.07^{a}	4.03^{a}	4.73^{a}	0.42^{a}	11.67^{a}
	LSD	2.62	0.09	0.115	0.055	4.294
	CV (%)	2.8	1.1	1.3	9.4	12.7
Ilu Gelan	Control	40.37^{d}	4.67^{c}	3.90^{c}	0.18^{c}	22.29^{b}
	Inorganic N and P fertilizers	42.70^{c}	4.47^{b}	4.37^{b}	0.29^{b}	15.32^{a}
	Fructón fertilizer alone	45.67^{b}	4.40^{b}	4.40^{b}	0.31^{b}	14.36^{a}
	Fructón + Inorganic N and P fertilizers	51.73^{a}	4.10^{a}	4.70^{a}	0.41^{a}	11.50^{a}
	LSD	2.294	0.088	0.23	0.057	5.729
	CV (%)	2.5	1.0	2.7	9.5	18.1

Means with the same letters in a column are not significantly different at 5% level of significance according to DMRT; LSD: least significant difference, CV: coefficient of variance; FD: fruit diameter; TSS: total soluble solids; TA: titrable acidity

The effect of sole and integrated use of inorganic nitrogen and phosphorus fertilizers, and organic *Fructón* fertilizer on the pH of tomato juice is shown in Table 6. The least pH values of tomato juice (4.03) in Toke Kutaye and (4.50) in Ilu Gelan were obtained from tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1). Plants with *Fructón* (50gL-1ha-1) also resulted in a higher pH value of tomato fruits compared to plots with inorganic nitrogen and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers and control treatments, although there was no statistically significant difference between them. At both experimental sites, the highest pH values of tomato juice (4.50) and (4.67) in Toke Kutaye and Ilu Gelan, respectively, were obtained from plots that received no fertilizer (control). These results are consistent with the results of Ilupeju et al. (2015), who reported that the combined application of 75% NPK and 25% Tithonia compost (organic) reduced the pH value of Roma VF tomato fruits compared to the control and the respective separate applications of the fertilizers alone.

According to Anthon *et al.* (2011), the pH value, which ranges from 4.25 to 4.4, is optimum for fresh tomato fruits to ensure desirable food safety. Teka (2013) further reported that tomato fruits that have a pH value greater than 4.4 are not suitable for processing as the pulp can be susceptible to thermophilic pathogens. Low pH values of tomato juice are associated with high fruit quality, which accounts for the flavor and sourness of the fruits (Aklile *et al.*, 2016). Thus, pH values as low as possible (up to the point that they do not adversely affect the taste) are desirable for industrial use. In the present study, the pH value of tomato juices varied from 4.03 to 4.5 in Toke Kutaye and from 4.1 to 4.67 in Ilu Gelan, respectively. Except for the control treatment, other treatments resulted in considerably higher-quality tomato fruits suitable for both processing and fresh consumption. The reduction of the pH value in tomato fruits applied with the combined application of *Fructón* and inorganic nitrogen and phosphorus fertilizers might be due to the high supply of potassium, nitrogen, boron, and molybdenum from the integrated application, which might increase the acid content of the fruits and thereby reduce the pH value of the fruit.

The result revealed that the total soluble solids (TSS) of tomato fruits were significantly ($P < 0.05$) influenced by the sole and integrated use of nitrogen and phosphorus fertilizers and organic sources (Table 6). The highest TSS values of tomato (4.73 ºBrix) and (4.7 ºBrix), which were harvested from the experimental sites of Toke Kutaye and Ilu Gelan, respectively, were recorded from the juice of tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1), followed by tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) and nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1), which were statistically similar when compared to each other. Conversely, the least TSS value (4.23 ºBrix) in Toke Kutaye and (3.90 ºBrix) in Ilu Gelan were recorded from the juices of tomato fruits prepared from tomato fruits harvested from control treatments. This result agrees with the findings of Shobo *et al.* (2017), who reported that combined application of poultry manure (PM) and NPK fertilizers resulted in a maximum TSS value in tomatoes compared to plants applied with poultry manure (PM), cow dung (CD), NPK, CD + NPK, and control treatments.

According to Tigist *et al.* (2013), the optimum TSS value for processing tomatoes ranges from 4.43 to 5.67 °Brix. A small increase in its value can significantly increase the product yield and decrease the costs of dehydration of pure sauce and paste (Bilalis *et al.*, 2018). The TSS value in this study ranges from 4.20 to 4.73 ºBrix in Toke Kutaye and 3.90 to 4.70 ºBrix in Ilu Gelan. Except for the control treatment, other treatments resulted in high-quality tomato fruits and increased the TSS value, which is suitable for both processing and fresh consumption. The increase in TSS value in tomato fruits applied with the combined application of *Fructón* and inorganic N and P fertilizers might be attributed to a high supply of nitrogen from the fertilizer sources, which contributed to the high production of TSS through a high rate of photosynthesis.

Total titratable acidity (TA) estimates the content of the organic acid in fleshy fruits, and it is one of the most important organoleptic quality factors for most fruits (Petriccione et al., 2015). The total TA content of tomato pulp varied significantly ($P < 0.05$) in fruits harvested from plots applied with different types of fertilizers (Table 6). The maximum TA values (0.42) in Toke Kutaye and (0.41) in Ilu Gelan, respectively, were obtained from the juice of tomato fruits harvested from the plots applied with *Fructón* (50 g L-1ha-1) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1), followed by tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) and chemical nitrogen and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers. Tomato plants applied with *Fructón* (50 g L-1ha-1) resulted in higher TA values compared to plants applied with inorganic nitrogen and phosphorus fertilizers and control treatments; however, there is no significant difference between organic *Fructón* and inorganic nitrogen and phosphorus fertilizers. At both locations, the lowest TA values (0.16) in Toke Kutaye and (0.18) in Ilu Gelan were recorded from the juices of tomato fruits harvested from control treatments. This result is in line with the findings of Al-Kharusi et al. (2009), who reported that the use of NPK, organic peat, and micronutrients resulted in a higher TA value in Khasab date fruit varieties as compared to plants applied with organic peat, NPK, and micronutrients and control treatments. Genanew (2013) suggested that an extreme reduction in the TA content of tomato fruits reduces the desirable quality of the fruit, and measures that minimize the reduction should be emphasized. The increment of the TA value in tomato fruits applied with the combined application of *Fructón* and inorganic fertilizers might be attributed to the reduction of pH values in this treatment due to the high potassium, nitrogen, boron, and molybdenum content, which increased the acid content of the fruits.

The total soluble solids (TSS) to total titratable acid (TA) ratio of tomato pulp varied significantly ($P < 0.05$) in fruits harvested from plots applied with different types of fertilizers (Table 6). The minimum TSS to TA ratio (11.67) in Toke Kutaye and (11.5) in Ilu Gelan, respectively, were obtained from the juice of tomato fruits harvested from the plots applied with *Fructón* (50 g L-1ha-1) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers, followed by tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) alone and chemical nitrogen and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers alone. However, the maximum TSS to TA ratio (26.67) in Toke Kutaye and (22.29) in Ilu Gelan were obtained from the juices of tomato fruits harvested from control treatments. The total soluble solids (TSS) to titratable acidity (TA) ratio often refers to the better-related palatability of the fruit than either sugar or acid levels alone (Genanew, 2013). According to Owusu et al. (2012), tomato fruits that have a TSS to TA ratio not greater than or equal to 10 are generally considered good-flavored quality fruits. For processing cherry-type tomatoes, the optimum TSS to TA ratio ranges from 9 to 15 (Samukelo and Linus, 2015). Hamdu et al. (2016) suggested that the reduction of organic acid ought to be retained to balance sweetness and acidity at an acceptable level for the human palate. The TSS to TA ratio in this study ranges from 11.67 to 26.67 in Toke Kutaye and 11.5 to 22.29 in Ilu Gelan. Except for the control treatment, other treatments resulted in considerably high-quality tomato fruits with an optimum TSS to TA ratio, which is suitable for both processing and fresh consumption.

Conclusion

The integrated use of inorganic nitrogen and phosphorus with organic *Fructón* fertilizer significantly improved the growth, yield, and quality of tomato fruits. Marketable yield and yield-related parameters of tomatoes, such as the number of fruit clusters, the number of fruits per cluster, and the number of fruits per plant, were significantly influenced by the combined application of *Fructón* and nitrogen and phosphorus fertilizers. A significantly higher marketable yield of tomato was obtained from the integration of 50 g L-1ha-1 *Fructón* with inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1) based on N equivalence with the recommended nitrogen and phosphorus fertilizer application. Therefore, it can be concluded and recommended that the integrated use of Fructón with inorganic nitrogen and phosphorus fertilizers be used to increase the yield and improve the quality of tomato fruits. However, further research is needed to determine the optimum rate of *Fructón* required to enhance the growth and yield of tomatoes.

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Conflicts of interest

The authors declare no conflict of interest.

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