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Effect of rabbit urine foliar spray on the yield and post-harvest quality of tomato (*Solanum lycopersicum* L.)

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Summary: Of all vegetable crops, tomato occupies the second-largest cultivated land after potato. However, its production is often lamed by insufficient nutrient supply and invasion by insect pests. Unlike inorganic fertilizers and synthetic pesticides commonly used, rabbit urine supplies nutrients to the crops, controls insect pests and has low mammalian toxicity. However, the most suitable rabbit urine foliar spray concentration for tomato production is currently unknown. The experiment was conducted in a randomized complete block design with six treatments and four blocks to evaluate the effect of different concentrations of rabbit urine foliar spray on the yield and post-harvest quality of tomato. The six treatments used include: five concentrations of rabbit urine (100%, 40%, 25%, 18.2% and 0%) and 0.1% Duduthrin 1.75EC. Results indicated that treatment 18.2% rabbit urine registered the highest marketable yield (129.14 t/ha) in trial 1. In trial 2, treatment 25% rabbit urine recorded the highest marketable yield (165.08 t/ha). These two treatments gave the highest marketable yields due to their sufficient nutrient supply, optimal pest control and zero foliage scorching. Unlike fruit firmness and sugar acid ratio, total soluble solids and titratable acidity increased with increase in rabbit urine concentration. Therefore, a rabbit urine foliar spray concentration of 25% optimally improves yield and post-harvest quality of tomato. More research work can be done to determine the effect of spraying intervals of rabbit urine on the yield and post-harvest quality of tomato.

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Key words: rabbit urine, tomato (*Solanum lycopersicum* L.), bio-fertilizer, bio-pesticide, yield, post-harvest quality

Introduction

Tomato is a member of the Solanaceae family, commonly termed as the nightshade family (Ochieng et al., 2016). The fruits are berries ranging from 1.5 cm to 7.5 cm in diameter and climacteric and develop in 7-9 weeks after fertilization of the ova (Costa et al., 2017).

Owing to the consumer awareness of the nutritional and medicinal value of tomato, demand for the crop's production has increased considerably (Kumar et al., 2017). For instance, 100 g edible tomato consists of about 1.98 g protein, 320 IU vitamin A, 31mg vitamin C and 1.8 mg iron (Rashid et al., 2016). Moreover, the lycopene antioxidant in tomato protects the human body from high blood pressure and cancers of the lungs, prostate glands and breasts (Bhowmik et al., 2012).

Crop nutrition is one of the abiotic factors that greatly influence the yield (Ochilo et al., 2019) and postharvest quality (Desta et al., 2022) of tomato. Pests and diseases are some of the biotic factors that negatively affect yield (Sumaili et al., 2021) and postharvest quality (Arah et al., 2015) of tomato. The nutrient composition of the fertilizer used affects the yield and post-harvest quality of tomato. For instance, excessive nitrogen supply encourages vegetative growth at the expense of fruiting, hence significantly reducing tomato yield. Moreover, high levels of titratable acidity were observed in tomatoes supplied with excessive potassium (Mao et al., 2024).

However, continued use of inorganic fertilizers and synthetic pesticides by farmers has its own drawbacks. For instance, inorganic fertilizers have led to the contamination of groundwater and soils, and therefore negatively affecting the ecosystem equilibrium (Morais et al., 2021). On the other hand, most of the locally available synthetic pesticides have been rendered ineffective due to resistance development by the target pests. Additionally, these pesticides are also harmful to human health, the environment and the natural enemies of tomato pests (Riley & Srinivasan, 2019).

Therefore, organic fertilizers and bio-pesticides are great alternatives that could be adopted to improve yield and post-harvest quality of tomato. Moreover, these products are cheaper than the inorganic fertilizers and synthetic pesticides (Desta et al., 2022).

Rabbit urine is a dual product that acts as both a bio-fertilizer and a bio-pesticide. As a bio-fertilizer, rabbit urine supplies crops with essential nutrients, majorly nitrogen, phosphorus and potassium (Yogeeshappa & Srinivasamurthy, 2017). For instance, the compositions of N, P and K in rabbit urine are higher by 2.72, 1.1 and 0.5%, respectively than in urine and feaces of cows, sheep, horses, buffalo, chicken and pigs (Sunadra et al., 2019). After diluting rabbit urine and commercial fertilizer samples at rates of 5 ml/L water and analyzing them in the laboratory, rabbit urine was reported to have 1.05, 0.01, 0.85 and 0.12% more N, P, K and Ca, respectively than the commercial fertilizer (Mutai, 2020). The high nitrogen content in rabbit urine is due to the fact that rabbits feed majorly on forage and drink very little water (Indabo & Abubakar, 2020).

As a bio-pesticide, it repels and kills insect pests like aphids, whiteflies and leaf miners (Lekamoi et al., 2022). Unlike inorganic fertilizers and synthetic pesticides, rabbit urine is environmentally friendly and has low mammalian toxicity (Kemunto et al., 2022). Since it is alkaline (pH 8.5), rabbit urine also neutralizes soil acidity caused by the commercial fertilizers (Mutai, 2020). Moreover, rabbit urine does not negatively affect the soil microbial enzymatic activities (Richert et al., 2011). Like any other livestock manure, rabbit urine increases soil organic matter content and soil aeration, thus leading to an improved microbial activity in the soil (Said et al., 2018).

Higher fruit sugar content was observed in strawberries harvested from plants treated with a combination of rabbit urine and potassium nitrate fertilizer as compared to those treated with potassium nitrate fertilizer alone (Sunadra et al., 2019). Therefore, the current study sought to determine the effect of rabbit urine foliar spray on the yield and post-harvest quality of tomato.

Materials and methods

Plant materials

Seeds of 'Anna F1', a tomato variety were obtained from Meya Agri Traders Limited in Nakuru, Kenya in 2022. Before transplanting, tomato seedlings were raised in a nursery bed. "Anna F1" is an indeterminate tomato variety with a long harvest period. It has a yield potential of up to 74 tons/acre under greenhouse conditions. Moreover, this variety was chosen due to its adaptability to a wide range of agro-ecological zones and high resistance to *Alternaria* stem canker, nematodes, *Verticillium* and *Fusarium* wilts (Sumaili et al., 2021).

Site description

The trial was conducted in two experiments. Experiment 1 ran from February to July 2022 while experiment 2 ran from August 2022 to January 2023. The two trials were performed at the Horticulture Research and Teaching Field in a high tunnel at Egerton University, Njoro, Kenya. The field is located at a latitude of 0º23′ S and longitude 35º35′ E in the Lower Highland III Agro-Ecological Zone (LH3) at an altitude of about 2238 m above sea level. The soils are well-drained *Mollic Andosols* with a pH of 6.0 to 6.5 (Jaetzold et al., 2009).

Treatments and experimental design

The study was conducted using randomized complete block design (RCBD) with six treatments and four blocks. The blocks were 2 m apart while the plots were 1 m apart. With each plot measuring 2.7 m by 1.5 m, the whole experimental area measured 34 m by 8 m. Due to the volatile nature of the sprays used in this study, individual plots were separated from each other by vertical polythene films. The side of each plot facing outside of the greenhouse was left open for ventilation. The treatments used include: five rabbit urine foliar spray concentrations (100%, 40%, 25%, 18.2% and 0%) and 0.1% Duduthrin 1.75 EC. The negative control was 0% rabbit urine and it consisted of water sprays only. The positive control was 0.1% Duduthrin 1.75 EC. The active ingredient of Duduthrin 1.75EC (registration number: PCPB(CR)-0481) is 17.5 g/L lambda cyhalothrin. These treatments were randomly allocated to the six plots in each block. Each plot was sprayed with 10L of the respective treatment solution at 7-day intervals. Spraying started three weeks after transplanting using 20-liter knapsack sprayers.

Crop establishment and maintenance

Healthy and vigorous 28-day-old seedlings were transplanted from the nursery bed into the experimental plots at a spacing of 60 cm x 45 cm (Sumaili et al., 2021). Each plot accommodated 21 tomato seedlings (7 rows, each row having 3 plants). During transplanting, di-ammonium phosphate (D.A.P 18% N, 46% P_2O_5) fertilizer was incorporated with soil in every planting hole at a rate of 150 kg/ha (69 kg P_2O_5/ha) (Monsanto Africa, 2020). The plots were weeded and irrigated regularly and uniformly.

In two equal splits, calcium ammonium nitrate (CAN 27%N, 8% Ca) fertilizer was used for topdressing at a rate of 200 kg/ha (54 kg N/ha). The first split was applied 2 weeks after transplanting while the second split followed 2 weeks after the first split application (Sumaili et al., 2021). NPK (17:17:17) fertilizer was also applied in two equal splits at a rate of 200 kg/ha. The first split was applied at the onset of flowering while the second split was applied 2 weeks after the first split application (Monsanto Africa, 2020). The tomato plants were single-stem pruned timely and uniformly across all plots. Using nylon twines and wires, the plants were trained immediately the plants reached 35 cm in height.

Data collection

Yield

In each plot, data was collected from six plants randomly selected from the middle rows. Harvesting commenced when fruits reached the breaker stage and this was done on weekly basis after the first harvest. Tomato fruits were harvested at the breaker stage in each plot once a week for six weeks after the first harvest. Harvesting began when first fruit(s) on any sample plant reached the breaker stage.

The harvested fruits were categorized as either being marketable or non-marketable. The marketable fruits had diameters of 4 cm and above and were free from cracks, blemishes, insect bites, disease infection and other physiological disorders. The non-marketable fruits had diameters below 4 cm and all types of physical defects. Fruit diameter was determined using a digital Vernier caliper. Marketable and non-marketable fruits from each plot were counted and later weighed separately using a portable electronic weighing balance (EK3001-JA 300 g AND company). The total number and weight of marketable and non-marketable fruits from each plot were converted into number of fruits per hectare (number/ha) and fruit weight in tons per plant (t/plant), respectively.

After the last harvest, the individual marketable and non-marketable yields for each plot were summed up separately to obtain total marketable yield and total non-marketable yield in terms of fruit weight and number per hectare. Both total marketable and total non-marketable yields were also summed up to obtain the grand total yield from each treatment in terms of fruit number (number/ha) and weight (t/ha).

Post-harvest quality

At the third week of harvesting, 15 fruits at breaker stage from each plot were selected for determining their post-harvest fruit firmness, total soluble solids, titratable acidity and sugar acid ratio. Each selected fruit had a diameter ranging between 4.5 and 6.5 cm. The selected fruits were also free from any form of physical disorders which could otherwise affect their normal post-harvest ripening. Fruits from different plots were placed on a bench in the biotechnology laboratory at the Horticulture Research and Teaching Field in Egerton University. Changes in firmness, total soluble solids, titratable acidity and sugar acid contents of the fruits were observed over storage time of 12 days.

***Fruit Firmness*:** Fruit firmness was determined using a hand-held penetrometer with 8 mm plunger size (model 62/DR, UK). Fruit firmness of 3 fruits was determined immediately after harvesting and this continued at 3-day intervals over the storage period of 12 days. The results obtained were recorded in Kg Force (KgF).

Total Soluble Solids (TSS) Content: Total soluble solids content of the same fruits used in fruit firmness determination was measured with the help of a hand-held refractometer (0-30 °Brix) (RHW Refractometer, Optoelectronic Technology Company Limited, UK). The procedure described by Majidi et al. (2011) was followed to determine fruit TSS content and the results were recorded as °Brix. This was also done at 3-day intervals for the storage period of 12 days.

***Titratable Acidity (TA)*:** The same sample fruits used in TSS analysis were used in determining the titratable acidity. This was also done at 3-day interval for the storage period of 12 days. The titration method explained by Al-Dairi et al. (2021) was used to determine the fruit titratable acidity content. About 5 ml of tomato juice was mixed with 95 ml distilled water. Thereafter, 2-3 drops of phenolphthalein indicator were added into the solution. This solution was then titrated against 0.1 N NaOH to determine the fruit titratable acidity content. Titratable acidity was expressed as a percentage of citric acid and, therefore, was calculated using the following equation:

$$\%\ \text{Citric Acid} = \frac{\text{Vol.NaOH (mL)} \times 0.1 \times 0.064}{\text{mL of juice or g of juice}} \quad \text{(equation 1)}$$

where, 0.1 is the normality of NaOH (N) and 0.064 is the citric acid milliequivalent factor.

***Sugar Acid Ratio*:** Sugar acid ratio was determined using the formula:

Sugar : acid ratio = °Brix value/ Percentage acid (equation 2)

Data analysis

SAS software (Version 9.4; SAS Institute, Cary, NC) was used to run Proc univariate procedure. This procedure was used to check for normality and equal variances assumptions of analysis of variance (ANOVA) of the data before analysis. Using the GLM procedure of SAS, data were then subjected to ANOVA at $P \leq 0.05$. At the F test, mean separation for significant treatments was done using Tukey's honestly significant difference (THSD) test at $P \leq 0.05$.

Results

Effects rabbit urine foliar spray on the total marketable yield of tomato

Rabbit urine foliar spray significantly influenced the total marketable yield as shown in ***Table 1*** below. In both trials, marketable yield of tomato increased with decrease in rabbit urine foliar spray concentration. During the first trial, 18.2% rabbit urine-treated plots registered significantly ($P \leq 0.05$) higher total number and total weight of marketable fruits per hectare (1,499,167 fruits/ ha and 129.14 t/ha, respectively) than the 0% rabbit urine- and 100% rabbit urine-treated plots. The total number and weight of marketable fruits per hectare in 0.1% Duduthrin 1.75EC–treated plots was not significantly different from those in treatments 18.2% rabbit urine, 25% rabbit urine and 40% rabbit urine.

During the second trial, the total number of marketable fruits per hectare from 25% rabbit urine-treated plots was significantly ($P \leq 0.05$) higher (1,710,852 fruits/ha) as compared to those from treatments 100% rabbit urine and 0% rabbit urine (negative control). The total number of marketable fruits per hectare in 0.1% Duduthrin 1.75EC-treated plots was not significantly different from those in the 18.2% rabbit urine-, 25% rabbit urine- and 40% rabbit urine-treated plots. The total weight of marketable fruits per hectare from treatment 25% rabbit urine was significantly ($P \leq 0.05$) higher (165.08 t/ha) as compared to the total marketable fruit weights from treatments 100% rabbit urine, 0% rabbit urine (water sprays or negative control) and 0.1% Duduthrin 1.75EC (positive control).

Table 1: Effects rabbit urine foliar spray concentrations on the total marketable yield per hectare (no/ha and t/ha) in trials 1 and 2.

Treatment	No/ha		t/ha	
	Trial 1	**Trial 2**	**Trial 1**	**Trial 2**
18.2% rabbit urine	1499167a	1619333a	129.14a	145.70ab
25% rabbit urine	1468315ab	1710852a	127.18a	165.08a
40% rabbit urine	1451722ab	1587963a	120.73a	132.83ab
100% rabbit urine	1130111c	700000b	82.63b	44.59d
0% rabbit urine	1270370bc	8707222b	107.58a	68.28cd
0.1% Duduthrin 1.75EC	1311593ab	1408556a	125.09a	107.72bc

*Means followed by the same letters within a trial are not significantly different according to Tukey's Honestly Significant Difference Test at $P \leq 0.05$.

Effects rabbit urine foliar spray on the total non-marketable yield of tomato

The total non-marketable yield was also influenced by rabbit urine foliar spray (***Table 2***). During the first trial, treatment 0% rabbit urine (negative control) registered a significantly ($P \leq 0.05$) higher total number of non-marketable fruits per hectare (198,852 fruits/ha) compared to treatments 25% rabbit urine and 0.1% Duduthrin 1.75EC. In the same trial, treatment 0% rabbit urine (negative control) also registered a significantly ($P \leq 0.05$) higher total weight of non-marketable fruits per hectare (12.93 t/ha) as compared to treatments 100% rabbit urine and 25% rabbit urine: 6L water. The total number and weight of non-marketable fruits per hectare from treatment 0.1% Duduthrin 1.75EC were not significantly different from those obtained from plots sprayed with 100% rabbit urine, 40% rabbit urine, 25% rabbit urine and 18.2% rabbit urine.

During the second trial, treatment 0% rabbit urine (negative control) registered a significantly ($P \leq 0.05$) the highest total number of non-marketable fruits per hectare (559,870 fruits/ha). The 0% rabbit urine-treated plots also registered a significantly ($P \leq 0.05$) higher total weight of non-marketable fruits per hectare (37.79 t/ha) as compared to the plots treated with 100% rabbit urine, 40% rabbit urine, 25% rabbit urine and 18.2% rabbit urine foliar sprays. In the same trial, the total number and weight of non-marketable fruits per hectare from treatment 0.1% Duduthrin 1.75EC was significantly (P≤0.05) different from those from treatments 25% rabbit urine, 40% rabbit urine and 100% rabbit urine.

Table 2: Effects rabbit urine foliar spray concentrations on the total non-marketable yield per hectare (no/ha and t/ha) in trials 1 and 2.

Treatment	No/ha		t/ha	
	Trial 1	**Trial 2**	**Trial 1**	**Trial 2**
18.2% rabbit urine	99296ab	131444bc	5.16ab	8.35bc
25% rabbit urine	54056b	86333c	2.02b	3.10c
40% rabbit urine	129759ab	65074c	6.55ab	10.71c
100% rabbit urine	123148ab	58463c	3.21b	2.23c
0% rabbit urine	198852a	559870a	12.93a	37.79a
0.1% Duduthrin 1.75EC	67667b	278535b	7.65ab	25.65ab

*Means followed by the same letters within a trial are not significantly different according to Tukey's Honestly Significant Difference Test at P≤0.05. Data were subjected to square root transformation before analysis but values presented are original means.

Effects rabbit urine foliar spray on the grand total yield of tomato

The grand total yield was also influenced by rabbit urine foliar spray (***Table 3***). In both trials, treatment 100% rabbit urine registered significantly (P≤0.05) the lowest grand total yields (both no/ha and t/ha). In both trials, the grand total yields (both no/ha and t/ha) obtained from treatment 0.1% Duduthrin 1.75EC was not significantly different from those obtained from treatments 18.2% rabbit urine, 25% rabbit urine and 40% rabbit urine. Treatment 18.2% rabbit urine registered the highest grand total yield (1598981 fruits/ha or 133.61 t/ha) in the first trial while treatment 25% rabbit urine registered the highest grand total yield (1797185 fruits/ha or 168.18 t/ha) in the second trial.

Table 1: Effects of rabbit urine foliar spray concentrations on the grand total yield per hectare (no/ha and t/ha) in trials 1 and 2.

Treatment	No/ha		t/ha	
	Trial 1	**Trial 2**	**Trial 1**	**Trial 2**
18.2% rabbit urine	1598981a	1750778a	133.61a	154.05a
25% rabbit urine	1521981ab	1797185a	129.20a	168.18a
40% rabbit urine	1581481a	1653037a	127.28a	143.54ab
100% rabbit urine	1253259b	758463b	85.88b	46.82c
0% rabbit urine	1469352ab	1430593a	120.50a	106.06b
0.1% Duduthrin 1.75EC	1385481ab	1687091a	129.81a	133.38ab

*Means followed by the same letters within a trial are not significantly different according to Tukey's Honestly Significant Difference Test at P≤0.05.

Effects rabbit urine foliar spray on the fruit firmness of harvested tomatoes

Rabbit urine foliar spray significantly influenced fruit firmness during storage (***Figure 1-2***). As expected, fruit firmness decreased with ripening of the stored fruits in both trials. In both trials, firmer fruits were recorded in treatments 0.1% Duduthrin 1.75EC (positive control) and 0% rabbit urine (negative control). Treatment 100% rabbit urine registered the lowest fruit firmness. The average fruit firmness in both trials for treatment 0.1% Duduthrin 1.75EC was 3.37 KgF in trial one and 3.39 KgF in trial 2 as compared to 2.70 KgF in trial 1 and 2.72 KgF in trial two for pure rabbit urine. Generally, fruit firmness decreased with increase in the rabbit urine foliar spray concentration in both trials.

Effects rabbit urine foliar spray on the total soluble solids (TSS) content of harvested tomatoes

Fruit TSS content was significantly influenced by the different rabbit urine concentrations over the storage period (***Figure 3-4***). Contrary to fruit firmness, total soluble solids content of tomato fruits from all treatments increased with ripening of the fruits. The highest total soluble solids contents were recorded in treatment 100% rabbit urine while the lowest were recorded in treatment 0% rabbit urine (negative control) in all sampling dates of both trials. The average TSS contents in both trials for treatment 100% rabbit urine was 3.23% in trial one and 3.28% in trial two as compared to 2.82% in trial one and 2.72% in trial two for treatment 0% rabbit urine (negative control). Fruit TSS content increased with increase in rabbit urine foliar spray concentration in both trials. In most sampling dates of both trials, there were no significant differences in fruit TSS content among treatments 18.2% rabbit urine, 25% rabbit urine, 40% rabbit urine and 0.1% Duduthrin 1.75EC.

Effects rabbit urine foliar spray on the titratable acidity (TA) content of harvested tomatoes

The titratable acidity content of tomato fruits during storage was also significantly influenced by rabbit urine foliar spray (***Figure 5-6***). Contrary to the TSS content, titratable acidity content of tomato fruits from all treatments decreased with ripening of the fruits. Treatment 100% rabbit urine registered the highest fruit titratable acidity content while treatment 0% rabbit urine (negative control) registered the lowest. The average titratable acidity contents in both trials for treatment 100% rabbit urine was 75.07% ppm in trial one and 74.88% ppm in trial two as compared to 53.62% ppm in trial one and 53.21% ppm in trial two for treatment 0% rabbit urine (negative control). Fruit titratable acidity increased with increase in the concentration of rabbit urine foliar spray in both trials. In most sampling dates of both trials, there were no significant differences in titratable acidity content among treatments 25% rabbit urine, 40% rabbit urine and 0.1% Duduthrin 1.75EC.

Effects rabbit urine foliar spray on the sugar acid ratio (TSS/TA) of harvested tomatoes

There were significant differences among the treatments in the sugar acid ratio of tomatoes during storage as affected by rabbit urine foliar spray (***Figure 7-8***). Fruit sugar acid ratio in all treatments increased with ripening of the fruits. Treatment 0% rabbit urine (negative control) registered significantly (P≤0.05) higher fruit sugar acid ratios than treatment 100% rabbit urine. The average sugar acid ratios in both trials for treatment 0% rabbit urine (negative control) was 533.60 in trial one and 518.63 in trial two as compared to 435.88 in trial one and 442.84 in trial two for treatment 100% rabbit urine. Tomato fruit sugar acid ratio decreased with increase in the concentration of rabbit foliar spray in both trials.

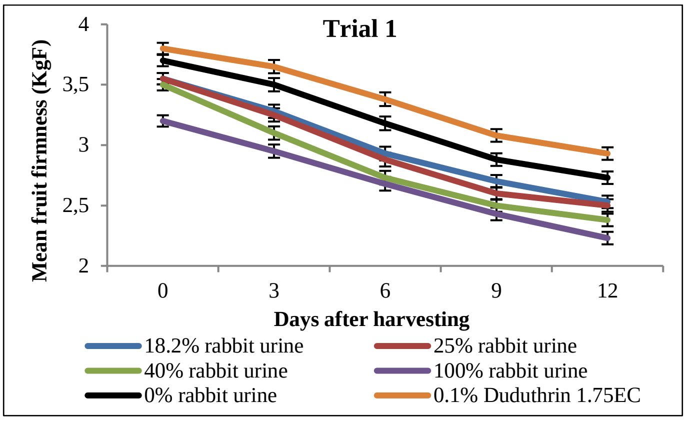

Figure 1: Effect rabbit urine foliar spray concentrations on tomato fruit firmness in trial 1.

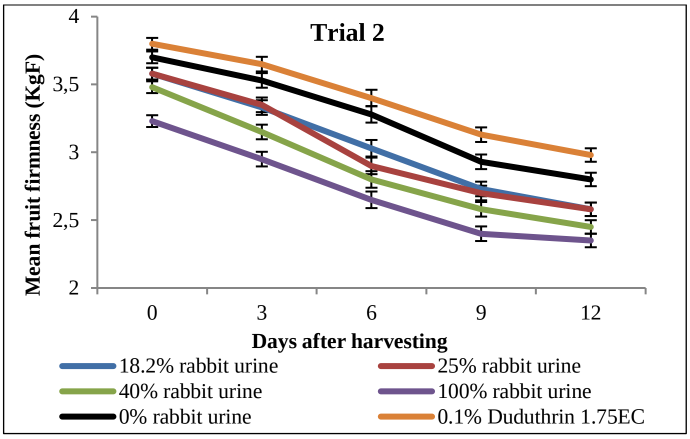

Figure 2: Effect rabbit urine foliar spray concentrations on tomato fruit firmness in trial 2.

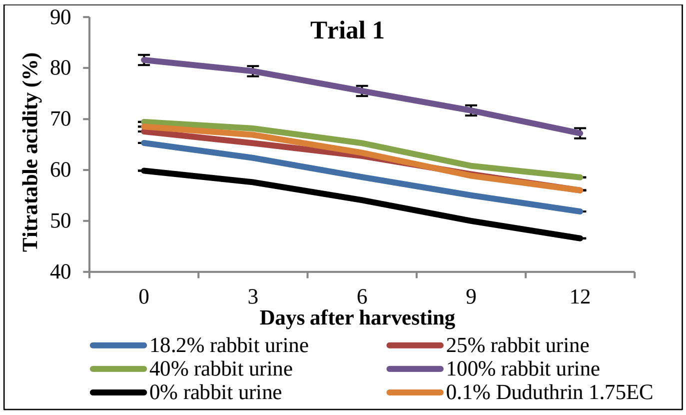

Figure 3: Effect rabbit urine foliar spray concentrations on the total soluble solids (TSS) content of tomato fruits in trial 1.

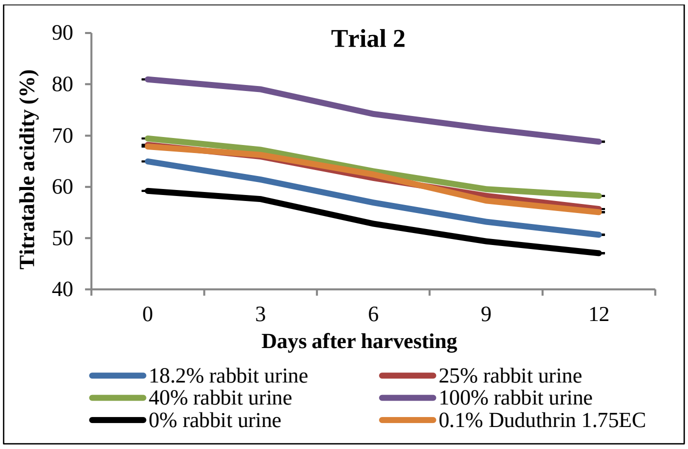

Figure 4: Effect rabbit urine foliar spray concentrations on the total soluble solids (TSS) content of tomato fruits in trial 2.

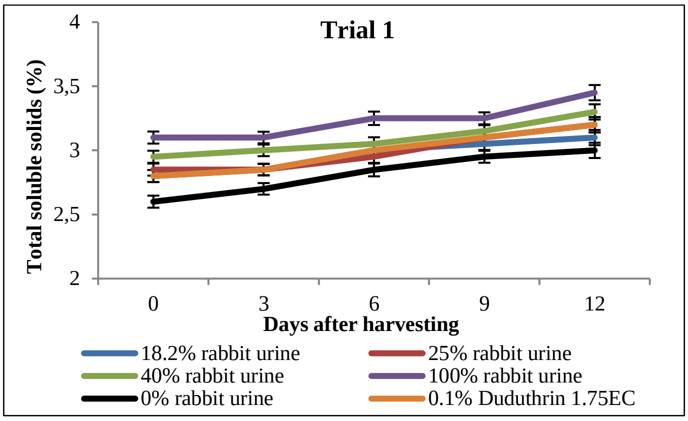

Figure 5: Effect rabbit urine foliar spray concentrations on the titratable acidity (TA) of tomato fruits in trial 1.

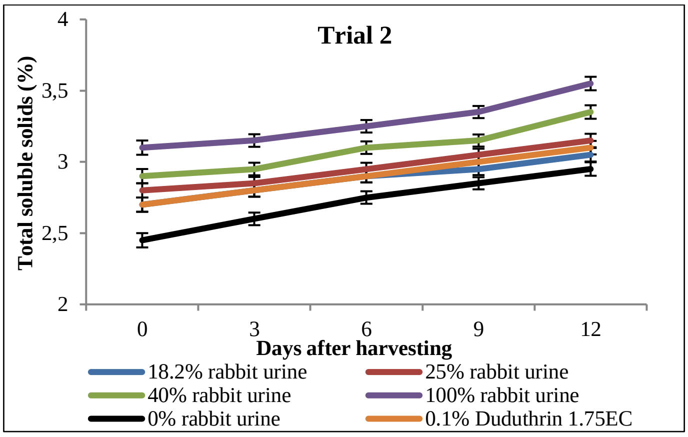

Figure 6: Effect rabbit urine foliar spray concentrations on the titratable acidity (TA) of tomato fruits in trial 2.

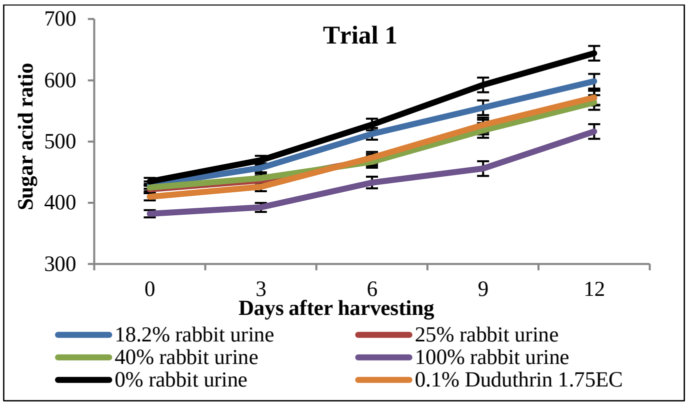

Figure 7: Effect rabbit urine foliar spray concentrations on the sugar acid ratio of tomato fruits in trial 1.

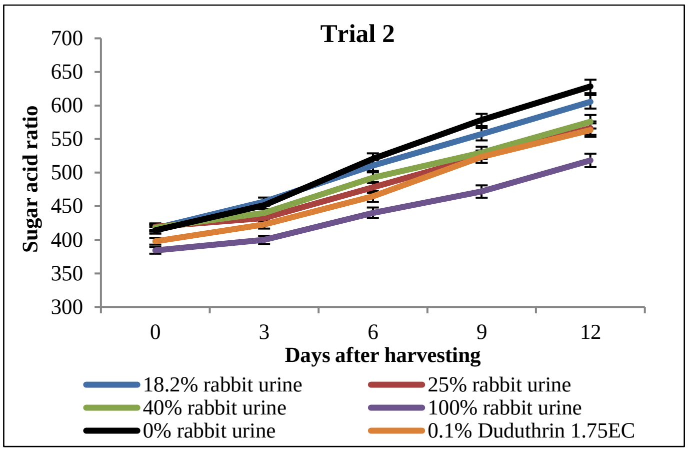

Figure 8: Effect rabbit urine foliar spray concentrations on the sugar acid ratio of tomato fruits in trial 2.

Discussion

Different concentrations of rabbit urine affected tomato yield. Moreover, it was noted that the scorching level of plant leaves was highest in plots sprayed with 100% rabbit urine (pure rabbit urine). Chaudhary et al. (2020) reported that early maturity is one of the major ways in which plants respond to the stress caused by foliage scorching. Therefore, this explains why 100% rabbit urine-treated plots gave the highest yields in the first harvesting week of both trials.

Using 100% rabbit urine, the grand total yield was lower than using any of the other treatments. Mutua et al. (2024) observed that the populations of insect pests of tomato like whiteflies reduce with increase in rabbit urine foliar spray concentration. Mutai (2020) also reported that the concentrations of macro-nutrients like N, P and K in rabbit urine are directly proportional to the concentration of urine. However, like the current study, Mutua et al. (2024) also reported that plant foliage scorching increased with increase in rabbit urine foliar spray concentration. This could therefore mean that although the 100% rabbit urine foliar spray optimally supplied the plants with nutrients and controlled insect pests effectively, plant foliage scorching was a major limiting factor that led to reduced grand total yields registered in the same treatment.

Moreover, under treatment 100% rabbit urine, the grand total yield was lower in the second trial than in the first trial. This could be due to high soil salinity caused by pure rabbit urine sprays over time. Machado & Serralheiro (2017) explained that accumulation of salts in the soil over time reduces tomato yield. Similarly, tomato yield in plots sprayed with 0% rabbit urine (negative control) was lower in the second trial than in the first trial. This could be due to the fact that water sprays neither supply any nutrients to the plants nor control pests effectively. Therefore, the plants could have faced problems to do with under-nutrition and build-up of insect pest populations over time, hence lower yields in the second trial.

Total marketable yield was highest in treatments 18.2% rabbit urine and 25% rabbit urine but lowest in treatments 0% rabbit urine (negative control) and 100% rabbit urine. Fruits harvested from 100% rabbit urine-treated plots had the least cases of insect damage, sooty mold covering and cracks. However, these fruits were very few and hence treatment 100% rabbit urine registered the lowest weights of marketable fruits. This could be due to the fact that treatment 100% rabbit urine reduced the photosynthetic area of the plants by scorching the foliage. Nogueira et al. (2022) reported that reduced photosynthesis led to reduces tomato produce. This therefore means that treatments 18.2% rabbit urine and 25% rabbit urine sufficiently supplied the plants with nutrients while controlling pests effectively without causing foliage scorching and high soil salinity over time, hence their high total marketable yields.

Using 0% rabbit urine (water sprays) gave the highest non-marketable yield in both trials. This could be due to pest build-up and lack of nutrient supply to the plant by the water sprays as compared to the rabbit urine sprays. Treatments 25% rabbit urine and 100% rabbit urine registered the lowest non-marketable yield. The non-marketable yield from treatment 0.1% Duduthrin 1.75EC (lambda cyhalothrin) was higher in trial two than in trial one. Ghosal et al. (2018) explained that synthetic chemicals like lambda cyhalothrin lead to the development of pest resistance over time and eventually leading to higher pest population due to resurgence of the pests.

According to Shehata et al. (2021), firmness and titratable acidity (TA) content of tomatoes decrease storage time increases. However, they reported that the total soluble solids (TSS) of tomatoes increase with increase in storage time. The results of the current study support this argument. Lang’at et al. (2018) explained that fruit firmness decreases with storage time due to enzymatic digestion of the cell wall and solubilization and depolymerization of pectin. Lekamoi et al. (2022) reported that rabbit urine contains salts like ammonium bicarbonate. The higher the rabbit urine concentration, the higher the rate of soil salinization (Mutai, 2020). Like the current study, previous studies by Ullah et al. (2020) suggest that tomato fruit firmness reduced with increase in soil salinity. However, the total soluble solids and titratable acidity contents of tomato increase with increase in soil salinity (Ilahy et al., 2022). Indabo and Abubakar (2020) also reported that rabbit urine contains high amounts of nitrogen. Further, Frías-Moreno et al. (2020) observed that increase in nitrogen supply reduces fruit firmness but increases the total soluble solids and titratable acidity in tomato. This, therefore, explains why fruits from plots sprayed with pure rabbit urine had the lowest firmness and the highest fruit TSS and TA contents among all other treatments. The sugar acid content of tomatoes also increases with increase in storage time after harvesting. This is because as the total soluble solids increase, the titratable acidity decreases with ripening of the fruit (Yeshiwas & Tolessa, 2018).

Conclusions

Rabbit urine foliar spray, both a bio-fertilizer and a bio-pesticide significantly influenced the yield (total marketable, total non-marketable and grand total yields) and post-harvest quality (total soluble solids, fruit firmness, titratable acidity and sugar acid ratio) of tomato. For optimum yield and post-harvest quality, it is recommended to use 25% rabbit urine foliar spray in tomato production. More research work can be done to determine the effect of spraying intervals of rabbit urine on the yield and post-harvest quality of tomato.

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