

**EFFECT OF RABBIT URINE FOLIAR SPRAY ON WHITEFLY POPULATION,
TOMATO (*Solanum lycopersicum*) YIELD AND FRUIT QUALITY**

ELVIS KALONZO MUTUA

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Requirements for the Master of Science Degree in Horticulture of Egerton
University**

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this university, or any other for award of a degree.



Signature

Date: 16/08/2024

Elvis Kalonzo Mutua

KM14/09044/20

Recommendation

This thesis has been submitted with our approval as University supervisors.



.....

.....16/08/2024.....

Signature

Date

Prof. Mariam Mwangi, Ph.D.

Department of Crops, Horticulture and Soils

Egerton University.



.....

..... 16/08/2024.....

Signature

Date

Prof. Liu Gaoqiong, Ph.D.

Department of Crops, Horticulture and Soils

Egerton University.

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DEDICATION

To my father, late mum, my wife, my son, brother, relatives and friends, with all my love and that of my Heavenly Father.

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ABSTRACT

Tomato (*Solanum lycopersicum*) is the second most important vegetable crop in the world after potato due to the growing awareness of its nutritional and health benefits. Whiteflies greatly contribute to low tomato yields in Kenya. Rabbit urine is both a bio-pesticide and as a bio-fertilizer. Therefore, the aim of this study was to determine the effects of rabbit urine foliar spray on whitefly population, yield and quality of tomato. The study was conducted inside a greenhouse at the Horticulture Research and Demonstration Field, Egerton University, Njoro from February to July, 2022 (trial 1) and August, 2022 to January, 2023 (trial 2). The experiment was set in a randomized complete block design (RCBD) with six treatments replicated four times. The treatments included: 0% v/v rabbit urine, 18.2% v/v rabbit urine, 25% v/v rabbit urine, 40% v/v rabbit urine, 100% v/v rabbit urine and 0.1% v/v Duduthrin 1.75EC. Individual plots were separated from each other by polythene films due to the volatile nature of the sprays. Data was collected on the following variables: whitefly populations, tomato yield, post-harvest fruit quality and repellent and toxicity effects of rabbit urine on adult whiteflies. Data obtained were subjected to analysis of variance (ANOVA) and treatment means separated using Tukey's Honestly Significant Difference Test at $P \leq 0.05$. Treatment 100% v/v rabbit urine recorded adult whitefly populations of as low as 0.7 and 0.8 whiteflies per plant at 42 DAT of trials 1 and 2, respectively. Repellence and mortality of adult whiteflies increased with increase in rabbit urine spray concentration. In trial 1, treatment 18.2% v/v rabbit urine registered the highest total marketable yield of 129.14 t ha⁻¹. In trial 2, treatment 25% v/v registered the highest total marketable yield of 165.08 t ha⁻¹. In both trials, treatment 100% v/v rabbit urine registered the lowest marketable yield of 82.63 t ha⁻¹ in trial 1 and 44.59 t ha⁻¹ in trial 2. Treatment 100% v/v rabbit urine registered the lowest fruit firmness of 2.23 KgF in trial 1 and 2.35 KgF in trial 2. However, treatment 100% v/v rabbit urine recorded the highest total soluble solids content of 3.55 °Brix and 3.45 °Brix in trials 1 and 2, respectively. Unlike fruit titratable acidity content, sugar acid ratio decreased with increase in rabbit urine foliar spray concentration. Therefore, 25% v/v rabbit urine foliar spray concentration is recommended for optimal whitefly control and improved yield and post-harvest quality of tomato.

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LIST OF ABBREVIATIONS AND ACRONYMS

AHDB	Agriculture and Horticulture Development Board
ANOVA	Analysis of Variance
AOAC	Association of Official Agricultural Chemists
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization of the United Nations Statistics
FPEAK	Fresh Produce Exporters Association of Kenya
Gov WAu	Government of Western Australia
HCD	Horticultural Crops Directorate of Kenya
ICES	International Credential Evaluation Service
KNA	Kenya News Agency
OECD	Organisation for Economic Co-operation and Development
SHEP PLUS	Smallholder Horticulture Empowerment and Promotion Project for Local and Up-scaling.

CHAPTER ONE

INTRODUCTION

1.1 Background information

Like any other country in the Sub-Saharan region, Kenya depends largely on agriculture for both food supply and economic growth (Ochilo *et al.*, 2019). Mwangi *et al.* (2020) reported that the agricultural sector records about 65% of Kenyan total exports and also contributes about 24% of the gross domestic product of the country. Horticulture is a key sub-sector of agriculture that has grown to become a main source of revenue to the Kenyan government and small-scale farmers while boosting food security and providing raw materials to the processing industry (Ochilo *et al.*, 2019). The annual contribution of horticulture to the Kenyan economy is about KES. 150 billion, at the same time supporting 6 million livelihoods (FPEAK, 2021). Vegetables, fruits, cut flowers, spices, root crops (Irish and sweet potatoes) and herbs are the main horticultural crops grown in Kenya (Ochilo *et al.*, 2019).

Tomato (*Solanum lycopersicum*) is the second most grown vegetable crop in the world after potato (Mwangi *et al.*, 2020). In 2019, the leading tomato producers globally were China (39.40%), India (11.91%) and Turkey (8.05%) (FAOSTAT, 2020). With an annual production of about 410,033 tonnes, Kenya remains among the top producers of tomatoes in the Sub-Saharan region (Ochilo *et al.*, 2019). The demand for tomatoes is rapidly increasing due to the growing consumer awareness of their medicinal and nutritional values (Kumar *et al.*, 2017). For instance, tomato contains about 1.98g proteins, 320 IU vitamin A, 31mg vitamin C and 1.8 mg iron in every 100g edible tomato (Rashid *et al.*, 2016). Tomato also has lycopene, an antioxidant that protects the body from prostate, lung and breast cancers, and high blood pressure (Bhowmik *et al.*, 2012).

Currently, tomato production accounts for 15.04% of horticultural produce and 38.11% of exotic vegetable output in Kenya. The leading Kenyan counties in tomato production are Kajiado (12%), Kirinyaga (10.2%) and Narok (9.5%) (HCD, 2019). Despite its economic importance and nutritional and medicinal values, tomato production in Kenya is still very low (Sigei *et al.*, 2014). In 2015, tomato yield in Kenya was about 21.1548 tonnes per ha ($t\ ha^{-1}$). In 2019, this yield dropped to about 20.3680 $t\ ha^{-1}$

(FAOSTAT, 2020). Ochilo *et al.* (2019) attributed this drop in tomato yield to abiotic stresses like poor soils, unreliable rainfall and high temperatures.

Barasa *et al.* (2019) also reported that biotic constraints like arthropod pests, bacterial, viral and fungal diseases have a major negative impact on tomato yields in Kenya. Whiteflies are among the major arthropod pests that attack tomato plants (Mutisya *et al.*, 2016). The whiteflies directly damage tomato plants by feeding directly on the plant and sucking phloem sap, hence weakening the plant and causing leaf and fruit spotting (Mutisya *et al.*, 2016). These pests also indirectly damage the plant by transmitting viral diseases that cause reduced yields and irregular fruit ripening (Tan *et al.*, 2014). Kiriimi *et al.* (2011) reported that growing tomatoes in greenhouses is an agricultural technique that has been used to curb both the environmental and pest problems. This has enabled farmers to produce tomatoes all year round, hence improving market prices.

Farmers have also opted to use chemicals like lambda cyhalothrin and neonicotinoids (imidacloprid and thiamethoxam) against whiteflies. However, continued use of these synthetic pesticides has led to whiteflies developing resistance against these chemicals. This has therefore rendered whitefly chemical control ineffective (Riley & Srinivasan, 2019). Moreover, Sani *et al.* (2020) observed that these chemicals have harmful effects on the natural enemies of whiteflies, human health and the environment. Breeders have also developed virus-tolerant tomato genotypes. However, these genotypes have become both unavailable and ineffective (Srinivasan *et al.*, 2012). Although biological control of whiteflies in greenhouse tomato production is well established, its efficacy under open field conditions is reduced and unreliable, hence unprofitable (Niemann *et al.*, 2021). Moreover, Roda *et al.* (2020) observed an increased number of necrotic rings on the tomato plants treated with parasitic wasps like *Eretmocerus modestus* and predatory mirids such as *Nesidiocoris tenuis*.

FAO (2012) reported a case study of farmers in Uganda who have been using both human and animal urine to control pests in their farms. Urine can also be used as a bio-fertilizer since it supplies essential nutrients like nitrogen, phosphorus and potassium to crops, hence improving productivity (Yogeeshappa & Srinivasamurthy, 2017). Specifically, rabbit urine has been proven by different farmers and researchers to not only

function as a foliar fertilizer, but also as a pesticide. Due to its pungent smell, rabbit urine is able to repel insect pests (Nonye, 2021). Using rabbit urine reduces the cost of buying synthetic insecticides since the rabbit urine can be used to repel whiteflies on crops like vegetables, bananas, macadamia, coffee and avocados (ICES, 2020). Other pests repelled by rabbit urine include: aphids, bugs, mites and leaf miners (Kemunto *et al.*, 2022). Rabbit urine is also considered to be environmentally friendly and has low mammalian toxicity (Kihaki, 2021; Nonye, 2021). However, different farmers have been using different dilution levels of rabbit urine on their crops due to lack of knowledge on the standard dilution level. For instance, urine: water ratios of 2L:9L (FarmKconnect, 2020), 2L:3L (FarmKconnect, 2020; ICES, 2020) and 2L:6L (ICES, 2020).

Therefore, the main aim of this research study was to determine the performance of different concentrations of rabbit urine foliar spray in the control of whiteflies as well as their effects on the yield and post-harvest quality of tomatoes.

1.2 Statement of the problem

Whitefly is one of the most important sap-sucking pests in tomato production. Whiteflies can cause up to 100% yield losses due to their direct feeding on tomato plants, hence weakening the plants. Whiteflies also secrete honey dew that encourages growth of sooty mold. Apart from covering the leaves and reducing their photosynthetic area, sooty mold also covers fruit surfaces and this makes them unmarketable. Whiteflies also transmit viral diseases that negatively affect plant growth, yield and quality of tomatoes. The annual economic losses incurred due to these diseases in the tropical and subtropical regions are about 161.2 million US dollars. Different control measures commonly used by farmers could be classified into chemical, biological and cultural control methods. However, most of these methods have been associated with various problems. For instance, whiteflies have developed resistance to different types of synthetic pesticides designed for its control. Moreover, these insecticides used are non-biodegradable and therefore leave toxic chemical residues in tomato fruits. These insecticides are also not environmentally friendly since they are harmful to the natural enemies of whiteflies, hence laming the efforts of whitefly chemical control. The insecticides work only by contact, hence lowering their efficacy against whiteflies. Although biological control of whiteflies in greenhouse tomato production is well established, its efficacy under open

field conditions is considerably low and unreliable, hence unprofitable. Additionally, reflective mulch only controls whiteflies effectively when the plants are young. Once the plants grow taller and the canopy covers the mulch, the reflective mulch is rendered ineffective. Different farmers use different dilution levels of the rabbit urine for foliar applications since no standard dilution level has been set. This has led to cases of underuse and overuse of rabbit urine. In Uganda for instance, some farmers have been using the urine in low concentrations which ineffectively control the whiteflies while others use very high concentrations which result to scorching of young plant leaves and salinization of the soil near the plant. Therefore, this study will contribute greatly in setting the standard concentration of rabbit urine that will reduce cases of overuse and underuse of rabbit urine foliar spray against whiteflies on tomato plants.

1.3 Objectives

1.3.1 Broad Objective

To contribute to food and nutritional security through the use of rabbit urine foliar spray for improved management of whiteflies, yield and quality of tomatoes.

1.3.2 Specific Objectives

- i. To determine the effect of rabbit urine foliar spray on the whitefly population on tomato plants.
- ii. To determine the repellent and toxic effects of rabbit urine foliar spray on whiteflies on tomato plants.
- iii. To determine the effect of rabbit urine foliar spray on the yield and post-harvest quality of tomatoes.

1.4 Hypotheses

- i. Rabbit urine foliar spray has no significant effect on whitefly population on tomato plants.
- ii. Rabbit urine foliar spray has no significant effect on the repellence and toxicity on whiteflies on tomato plants.
- iii. Rabbit urine foliar spray has no significant effect on the yield and post-harvest quality of tomatoes.

1.5 Justification

For the improvement in production of tomato to remain constant, new approaches related to whitefly control should be employed to achieve profitability while at the same time contributing to environmental conservation. Rabbit urine has proven to be a dual purpose foliar spray on vegetable crops like kales, cabbages and carrots (Nonye, 2021). Apart from supplying essential nutrients like nitrogen, phosphorus and potassium to the crops, rabbit urine controls soft-bodied insect pests such as whiteflies and aphids (Yogeeshappa & Srinivasamurthy, 2017). Like some of the synthetic pesticides commonly used, rabbit urine has two modes of action against whiteflies – repellence and killing. Since rabbit urine has low mammalian toxicity and is environmentally friendly, there are no cases of chemical residue in agricultural produce and threats to the natural enemies of the whiteflies by the rabbit urine. Therefore, the use of rabbit urine foliar spray is an important intervention in the control of whiteflies since this method is effective and safer to the environment and human health. At the end of this project, a standard concentration of rabbit urine foliar spray as a bio-pesticide will be established to help the farming community overcome the challenges of underutilization and wastage of rabbit urine in the control of whiteflies in tomato production. This will also contribute positively towards improvement of the organic farming sector and thus enhancing sustainable horticulture. The standard concentration of rabbit urine as an insecticide will be set and more awareness on its effectiveness in controlling whiteflies will be made via publications. This will encourage more tomato and other vegetable farmers to rear rabbits so as to supply rabbit urine cheaply instead of buying it, since rabbit rearing is one of the cheapest agri-enterprises. Therefore, mixed farming system will grow and this will greatly boost food security not only in Kenya and Africa, but also globally. The success of this project will benefit the tomato farmers with more improved information on rabbit urine utilization.

CHAPTER TWO

LITERATURE REVIEW

2.1 Tomato (*Solanum lycopersicum*)

2.1.1 Botany of Tomato

Tomato is a member of the *Solanaceae* family, commonly referred to as a nightshade family (Ochieng *et al.*, 2016). Its growth habit can either be determinate or indeterminate (Sigei *et al.*, 2014). Tomato reaches maturity in 90-100 days after transplanting (OECD, 2017) and can grow up to 3 m in height (Oso, 2020). Since the vegetative phase is very short, flowering and fruiting overlap with vegetative growth (Costa *et al.*, 2017). Apart from being a dicotyledonous herbaceous plant, a mature tomato plant has angular, fibrous and hairy stems (Costa *et al.*, 2017). The stem is also covered with glandular trichomes with a characteristic smell (OECD, 2017).

The plant has leaves (≤ 32 cm long) that vary from lobed to compound, alternately arranged on the stem and possess pinnately arranged segments (Costa *et al.*, 2017). The compound leaves consist of 5-9 petiolated and dentated leaflets (Oso, 2020). Like the stems, all leaves are covered with glandular and hairy trichomes (OECD, 2017). The fruits are berries ranging from 1.5 cm to 7.5 cm in diameter (OECD, 2017) and climacteric and develop in 7-9 weeks after fertilization of the ova (Costa *et al.*, 2017). The fruit color ranges from yellow to red orange (Costa *et al.*, 2017). Their shape ranges from oval to almost spherical, and they elongate to pear-shaped berries. The outer skin of the fruit is thin and the fruit's predominant red color is attributed to a carotenoid called lycopene while the beta-carotenoids give the fruit an orange color. The fruits also contain tomatine, an alkanoid with fungicidal properties used to determine the taxonomy of the species. Tomatine level decreases as the fruit matures (OECD, 2017).

The seeds are both small (40 mm^3) and lentil-shaped (OECD, 2017). However, different cultivars have different number of seeds (Costa *et al.*, 2017). The primary root can grow up to 5 m long depending on the genotype and soil type. The secondary roots grow when the main root undergoes stress during the transplanting process (Costa *et al.*, 2017).

2.1.2 Origin and distribution of tomato production

The name 'tomato' was derived from the word 'tomatl' of the Nahuatl tongue of Mexico (Amare & Gebremedhin, 2020). The wild species of tomato are closely related to the cultivated species and are believed to be natives of the Andes Mountains of South America, probably Peru and Ecuador (Costa *et al.*, 2017). Tomato was first domesticated in the Pre-Columbian Mexico before distribution to the rest of the world. Italian breeders developed the first improved tomatoes by genetically converting the small wrinkled and hard tomatoes into today's red-colored smooth and juicy varieties (OECD, 2017).

Currently, tomato is the world's second most important vegetable crop after potato (Sumaili *et al.*, 2021). It is grown for both domestic and export markets, with an increasing demand from the processing industry (Mutisya *et al.*, 2016). In 2019, the world's and Africa's total tomato productions were about 180.77 and 21.66 tonnes (FAOSTAT, 2020). Globally, China is the leading producer of tomatoes (Sumaili *et al.*, 2021) whereas Egypt and Nigeria are Africa's top producers of tomato (Oso, 2020). Currently, Kenya's tomato production volume is ranked 8th in Africa and 37th globally (Sumaili *et al.*, 2021).

Tomatoes can be grown either in open field or under greenhouse conditions (Barasa *et al.*, 2019). The greenhouse tomato production in Kenya is growing steadily, even among small-scale farmers (SHEP PLUS, 2019). The indeterminate varieties like Anna F1, Samantha F1, Chonto F1, Harmony F1, Bravo and Prostar F1 are grown in the greenhouse. The determinate varieties like Rambo F1, Riogrande F1, Joy F1 and Faulu are grown in the open fields (Sigei *et al.*, 2014).

2.1.3 Uses and Health Benefits of Tomato

Tomato is a basic ingredient in a huge variety of raw, cooked or processed foods (OECD, 2017). It can be eaten raw in salads, served as cooked vegetables, pickled or as an ingredient for various prepared dishes (Oso, 2020). Tomato can also be used for processing to make tomato juice, ketchup, puree, canned tomatoes and dehydrated pulp (Sumaili *et al.*, 2021).

The fruit has large amounts of water, low quantities of fats and proteins, minerals and carbohydrates (OECD, 2017). It also has vitamin A in the form of carotenoids like lycopene; vitamins B, C and E and phenolic compounds (flavonoids, phenolic acid and

tannins) that prevent chronic diseases like coronary heart disease, hypertension and diabetes (Oso, 2020). Lycopene is one of the most powerful natural antioxidants that prevent prostate cancer and arthritis (Rashid *et al.*, 2016).

2.1.4 Challenges facing tomato production in Kenya

In spite of its growing demand, uses and health benefits in Kenya, the country's current tomato yield is as low as 20.4 t ha⁻¹, compared to world's 35.9 t ha⁻¹ (FAOSTAT, 2020). Sumaili *et al.* (2021) associated these low yields to both abiotic and biotic stresses. They further explained that the main biotic constrains in tomato production are nematodes, diseases and insect pests like the whiteflies.

2.2 Whitefly (*Aleyrodidae spp*) as an Important Pest of Tomato

Whiteflies are *Homopterans* belonging to the Family *Aleyrodidae* (Ghosal *et al.*, 2018). The bodies and wings of the adult flies are covered with a fine powdery white wax. Whiteflies are mainly tropical insect pests but are also found in the warmer regions of the globe and in greenhouses in the temperate regions. The adult whiteflies are small insects with an average body length of 1-3 mm (Fiallo-Olivé *et al.*, 2020). They have an elongated somewhat triangular body shape, which is mostly gray-white in color (Gardentech, 2018). Whiteflies hide themselves on the underside of the leaves (Plate 1) and fly readily when the plants are disturbed (Srinivasan *et al.*, 2012).



Plate 1: Whiteflies on the underside of a tomato leaf (Source: Welty, 2018).

Whiteflies affect tomato yield and quality both directly and indirectly (Mutisya *et al.*, 2016). Direct effect is evident when the whiteflies physically feed on the plant and suck sap from the phloem, resulting to spots on leaves and fruits and weakening of the plant (Perring *et al.*, 2018). Ghosal *et al.* (2018) observed that the plant leaves whose sap has been sucked by the whiteflies appear pale and wilted. Spotted fruits have low marketable value whereas weak, wilted and pale plants with spotted leaves give low yields of low quality (Perring *et al.*, 2018).

Tan *et al.* (2014) classified disease transmission and honeydew secretion as the main indirect effects of whitefly invasion on tomato yield and quality. Mutisya *et al.* (2016) explained that whiteflies excrete honeydew, which favours growth of sooty mould on the tomato plants. This sooty mould covers the leaves of plants, hence reducing the photosynthetic capacity of the plants while lowering the aesthetic quality and marketability of the fruits (Shukla *et al.*, 2016). The honey dew also attracts ants that feed on and weaken the plants (Bharathi, 2015).

Whiteflies also carry and spread viral diseases that have a global impact on tomato production (Mutisya *et al.*, 2016). The annual economic losses incurred due to these diseases in the tropical and subtropical regions are about 161.2 million US dollars (Li *et al.*, 2021). Khamis *et al.* (2021) also observed that the main viruses transmitted to tomato plants by whiteflies include: Tomato Chlorosis Virus (ToCV), Tomato Yellow Leaf Curl Virus (TYLCV) and Tomato Infectious Chlorosis Virus. During sap sucking, whiteflies also transmit plant viruses that cause some physiological disorders such as chlorotic streak and irregular ripening of tomatoes (Dong *et al.*, 2014). Khamis *et al.* (2021) further reported that whitefly invasion can cause over 50% losses in crop yield. The damage is even more severe when the tomato plants are water stressed (Infonet-Biovision, 2021).

2.2.1 The Life Cycle of Whiteflies

All whitefly types have similar life cycles comprising of the egg, four instar nymphs and adult stages of development (Plate 2) (Gov WAu, 2018). Sani *et al.* (2020) observed that the entire life cycle lasts for 16-31 days, depending on temperature, relative humidity and the host plant. The life cycle is shortened with an increase in temperature

(Chandi *et al.*, 2021). Sani *et al.* (2020) further recorded that 28°C is the most ideal temperature for whitefly egg production.

The female adult lays eggs in clusters of 5-6 eggs on the underside of the leaves (Sood *et al.*, 2014), with the long axis of the egg laying perpendicular to the leaf while the wide end touches the leaf surface (Gangwar & Gangwar, 2018). The eggs are pear shaped and initially white but darken with time (Sani *et al.*, 2020). Sood *et al.* (2014) observed that the eggs are averagely 0.201 mm long and 0.096 mm wide.

After 5-7 days at 30°C, the egg hatches into the first instar nymph (Gangwar & Gangwar, 2018). The first instar is also called the crawler and it is flat, oval and scale-like in shape (Gangwar & Gangwar, 2018; Gov WAU, 2018). After hatching, it starts feeding on the leaf phloem until it molts into the three subsequent instars (Sani *et al.*, 2020). The first instar nymph is the only nymph stage that is mobile (Gangwar & Gangwar, 2018). Sood *et al.* (2014) also observed that this instar has a body length of about 0.267 mm and a breadth of 0.145 mm. They also stated that as the first instar nymph molts, the antennae and legs are lost, resulting into sessile second, third and fourth instar nymphs.

The second and third instar nymphs are pale green in color and resemble the scales in appearance (Gov WAU, 2018). Their body lengths are about 0.37 mm and 0.658 mm, respectively while their breadths are about 0.217 mm and 0.377 mm, respectively (Sood *et al.*, 2014). The fourth instar nymph feeds at first, before feeding stops to usher in the formation of the adult whitefly (Gov WAU, 2018). The fourth instar nymph is also called the 'red-eye nymph' since the relatively huge eyes of the developing adults can be seen through the nymph skin during this stage (Gangwar & Gangwar, 2018). The fourth instar is about 0.728 mm long and 0.415 mm wide (Sood *et al.*, 2014). The nymphs remain fixed to the plant while feeding for about 4 weeks until the adult stage. At 21°C, the whitefly spends 3-4 days as the first instar nymph, 4-5 days as the second instar nymph and 4-5 days as the third instar nymph (Gangwar & Gangwar, 2018).

After emergence, the adults are at first pale green or yellow in color, before they are covered in a white waxy powder (Gangwar & Gangwar, 2018; Gov WAU, 2018). Sood *et al.* (2014) observed that the males are smaller than the females, with difference in body length and breadth of about 0.12 mm and 0.44 mm, respectively. The lifespan of the

female adult is up to 60 days while that of the male adult is about 9-17 days. Each female adult can oviposit about 300 eggs during the lifespan (Gangwar & Gangwar, 2018). About 11-15 generations of whiteflies can occur within a single year, and this is influenced by climatic conditions (Gangwar & Gangwar, 2018). All stages of development are always found on the plant leaves (Gov WAu, 2018) while sucking sap from the leaves and excreting honeydew (Sood *et al.*, 2014).

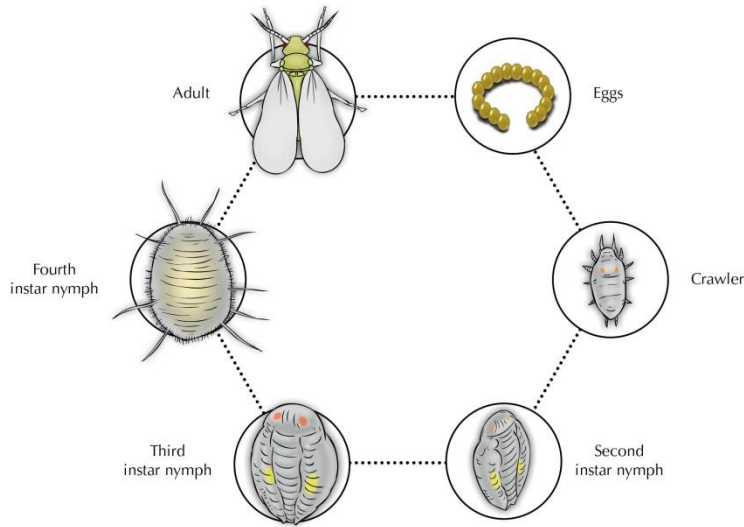


Plate 2: The life cycle of whiteflies (Source: Syngenta Ornamentals, 2020).

2.2.2 Current Control Measures and their Limitations

To control whitefly populations, tomato farmers mainly employ chemical, biological, cultural and physical measures (Shukla *et al.*, 2016).

(i) Chemical control

Sani *et al.* (2020) reported that chemical control is the most commonly used method in whitefly eradication due to the immediate action of the insecticides against the pest. However, due to the continued use of these synthetic insecticides, whiteflies have developed resistance against them (Ghosal *et al.*, 2018). For instance, the tobacco whitefly (*Bemisia tabaci*) has developed resistance to over 40 active ingredients of synthetic pesticides arising from repeated application of higher doses of the pesticides (Naveen *et al.*, 2017). Some insecticides that whiteflies have developed resistance against include: conventional insecticides (organophosphates and organochlorines) and insect

growth regulators like buprofezin and pyriproxyfen (Horowitz *et al.*, 2011). Under laboratory conditions, whiteflies developed early resistance to bifenthrin and the resistance intensified under continuous selection to 752-fold by generation F₂₇ (Bethke, 2020). Repeated applications of excessive doses of neonicotinoides also leads to whiteflies developing pesticide resistance (Smith *et al.*, 2020).

Ghosal *et al.* (2018) reported that whitefly resistance to synthetic pesticides is a process of natural selection. They further elaborated that farmers use more chemicals due to the resurgent behavior of whiteflies, hence posing more threat to natural enemies of whiteflies. For instance, Ghosal *et al.* (2018) observed that imidacloprid was very toxic to some species of spiders, bugs and predatory beetles, which are natural enemies of the whiteflies. This further led to secondary outbreak of the whiteflies. Further, Rodrigues *et al.* (2013) recorded that lambda cyhalothrin was toxic to lady beetles, which are also predators of the whiteflies. Apart from endangering the existence of the natural enemies of whiteflies, these insecticides are toxic to human health since their residues are persistent in crop produce. Moreover, these chemicals are non-biodegradable, hence harmful to the environment (Ochilo *et al.*, 2019). Therefore, whiteflies resistance to insecticides can be solved by a novel approach that makes maximum use of non-chemical methods for controlling the pest (Žanić *et al.*, 2018).

(ii) Biological control

Although biological control of whiteflies in greenhouse tomato production is well established, its efficacy under open field conditions is considerably low and unreliable, hence unprofitable (Niemann *et al.*, 2021). Smith and Krey (2019) reported cases of successful uses of parasitic wasps (*Eretmocerus eremicu* Rose and *Eretmocerus mundus* Mercet) in the United States and predatory mirids (*Macrolophus pygmaeus* Wagner and *Nesidiocoris tenuis* Rumbur) in Europe to control *Bemisia tabaci* whitefly. However, Roda *et al.* (2020) observed more damage (number of necrotic rings) on the tomato plants treated with *Eretmocerus modestus* and *Nesidiocoris tenuis* than in those plants treated with *Macrolophus praeclarus*.

Liu *et al.* (2014) observed that the performance of a parasitic wasp like *Encarsia formosa* depends largely on the cryptic species of *B. tabaci* (B and Q) and TYLCV infestation on the host plants. Liu *et al.* (2014) further reported a lower parasitism rate,

longer developmental time, lower longevity but lower mortality rate of *E. formosa* in *B. tabaci* Q than in B on healthy plants. This therefore indicated a serious challenge in using *E. formosa* to control *B. tabaci* Q.

(iii) Cultural and physical control

These methods mainly involve creating unfavorable conditions for the whiteflies (Sani *et al.*, 2020). For instance, Sani *et al.* (2020) explained that although electric field screens on greenhouse windows can prevent whitefly entry, this method further requires a guard at the greenhouse entrance which makes the method expensive. Riley and Srinivasan (2019) observed that reflective mulch controls whiteflies by interfering with their settlement on the host plants by interfering with the visual cues of the pests. However, the authors reported that this tactic has been found to be only effective until the plant canopy develops and covers the mulch surface. Furthermore, this method is costly and hence many farmers are reluctant to adopt it.

Tosh and Brogan (2015) observed that the volatiles from cucumber, dwarf French bean and courgette plants did not strongly affect the behavior of whiteflies, rendering the plant volatiles ineffective.

Through breeding, transgenic plants that can easily be supplied by seeds have been developed. However, no transgene has yet been reported to have stable resistance to whitefly invasions (Shukla *et al.*, 2016). Srinivasan *et al.* (2012) also observed that the tomato genotypes that were developed and expected to exhibit tolerance/resistance to the viral diseases caused by whiteflies are both ineffective and unavailable. They further explained that these genotypes can harbor large numbers of whiteflies that in turn increase viral disease incidence on the tomato plant, hence reduced yields and quality. Srinivasan *et al.* (2012) also reported that although these genotypes do not show typical symptoms of the Tomato Yellow Leaf Curl Virus attack, they are not immune to the disease.

Therefore, owing to the drawbacks of the above mentioned control measures, there is need to come up with a more effective, environmentally friendly and safer method to control whiteflies in tomato production (Zafar *et al.*, 2016).

2.3 Rabbit Urine

In addition to being environmentally friendly and non-toxic to natural enemies of whiteflies, rabbit urine is considered to have low mammalian toxicity (Nonye, 2021). Moreover, rabbit urine can be used as both an insecticide against whiteflies and aphids (Soko, 2020) and as a bio-fertilizer (FarmBiz Africa, 2019). Rabbit urine use is cheaper than synthetic insecticides since the urine can be sourced through rabbit keeping (Mutai, 2020) and also it can be used without further treatment (Indabo & Abubakar, 2020).

2.3.1 Rabbit Rearing in Kenya and its Benefits

Rabbit rearing in Kenya is no longer taken as a leisure time activity but is currently commercialized, hence its steady growth rate. This is due to farmers realizing the multiple benefits resulting from the enterprise (FarmKonnnect, 2020; Mutsami & Karl, 2020; Nonye, 2021). For instance, fur, manure and urine are the most demanded rabbit products in the organic farming sector (KNA, 2021), while rabbit meat is demanded mostly in the urban areas (Mutsami & Karl, 2020). Rabbit urine has been reported to double the income of rabbit farmers in Kenya (Xinhua, 2014).

Interestingly, rabbits are easy and cheap to rear since they can be raised on grain-free diets and can easily adapt to more ecosystems than other ruminants. They can survive by feeding on garden forage only (Kemunto *et al.*, 2022). Their housing requires very little space (Xinhua, 2014). Rabbits have early maturity due to their fast growth rate, high fecundity (Mutsami & Karl, 2020) and very high feed conversion efficiency (Xinhua, 2014). A mature doe can produce more than 40 kits per year (Mutsami & Karl, 2020).

Rabbit urine is of more economic value than urine from goat and cattle because of its good performance and low cost of supply (Kemunto *et al.*, 2022). One rabbit can produce about 250 mL of urine per day (Nderitu, 2020).

2.3.2 Collection of Rabbit Urine

Fix a wire mesh at the bottom of the cage with corrugated plastic sheets underneath (Xinhua, 2014). Connect the sheets to a gutter that leads the urine into a collecting container (Kihaki, 2021). The gutter should be made of plastic since rabbit urine can rust quickly and corrode metal surfaces (Waterbury, 2019).

2.3.3 Uses of Rabbit Urine in Crop Production and Its Composition

Rabbit urine has been reported to repel insect pests like bugs, aphids, leaf miners and mites by its pungent smell. The pungent smell is due to high ammonia content in the rabbit urine (Nonye, 2021). Moreover, some smallholder farmers in Kenya and Uganda have been using rabbit urine to control whiteflies from vegetables (FarmBiz Africa, 2019; ICES, 2020). Nonye (2021) stated that rabbit urine repels insect pests by its pungent smell. For instance, potato farmers in Cameroon have been using rabbit urine to control whiteflies and aphids in their farms (Temfack *et al.*, 2021). Mohammed and Kilalo (2016) stated that rabbit urine had a higher efficacy in controlling aphids in common beans than wood ash.

Rabbit urine can be used as a biogenic fertilizer since it contains 2.72% nitrogen, 8.7% phosphorus, 2.3% potassium, 3.6% Sulphur, 1.26% calcium and 4.0% magnesium (Tarigan *et al.*, 2016). The nitrogen is in urea form that breaks down into ammonium and nitrate forms while the phosphorus, potassium and sulphur are in ionic forms (Yogeeshappa & Srinivasamurthy, 2017). According to Sunadra *et al.* (2019), 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 faeces of cows, sheep, horses, buffalo, chicken and pigs. After diluting rabbit urine and commercial fertilizer samples at rates of 5 ml/L water and analyzing them in the laboratory, Mutai (2020) reported that rabbit urine had 1.05%, 0.01%, 0.85% and 0.12% more N, P, K and Ca, respectively than the commercial fertilizer used in Kenya. Indabo and Abubakar (2020) stated that the high nitrogen content in rabbit urine is due to the fact that rabbits feed majorly on forage and drink very little water.

Sunadra *et al.* (2019) observed that fresh weight of melon fruits increased with an increase in the concentration of rabbit urine foliar spray. For instance, rabbit urine foliar spray concentration of 0.3% gave the highest fresh fruit weight per plant (851.72 g) while 0% (no rabbit urine spray) gave the lowest (680.96 g). Sunadra *et al.* (2019) explained that the number of leaves per plant and root mass also increased with increase in rabbit urine foliar spray concentration. Therefore, fresh fruit weight was highest in plants sprayed with a rabbit urine spray concentration of 0.3% due to increased photosynthetic capacity of the plants.

Moreover, greater number of fruits, fruit length, fruit diameter, fruit sugar content and yield were observed in strawberry 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).

Yogeeshappa and Srinivasamurthy (2017) observed the highest tomato fruit number and fruit weight in tomato plants treated with human urine, followed by those treated with cattle urine and lastly in those plants treated with chemical fertilizer. Therefore, since rabbit urine is considered a stronger biogenic fertilizer than cattle and human urine, its performance on yield and quality of tomato will be investigated in this experiment.

2.3.4 Application of Rabbit Urine as a Fertilizer and Pesticide

Apart from adding N, P, K and Ca to the soil, rabbit urine neutralizes the soil acidity caused by the commercial fertilizers because rabbit urine is alkaline (pH 8.5) (Mutai, 2020). FAO (2012) reported that soil salinization can occur due to large amounts of salts in the urine.

Rabbit urine foliar spray does not negatively affect the soil microbial enzymatic activities (Richert *et al.*, 2011). Like any other livestock manure, rabbit urine can increase soil organic matter content and soil aeration, thus leading to an improved microbial activity in the soil (Said *et al.*, 2018).

Different farmers have been using different dilution levels of rabbit urine when applying it to their crops as a foliar feed and a pesticide. For instance, urine: water ratios of 2L:9L (FarmKonnnect, 2020), 2L:3L and 2L:6L (FarmKonnnect, 2020; ICES, 2020). The right dilution level should be used to promote better crop yield (Mutai, 2020). High concentrations of rabbit urine will scorch young plant tissues (FAO, 2012; FarmKonnnect, 2020). To avoid serious cases of soil salinization, apply plain water to the plant after spraying in dry areas or during dry seasons (FAO, 2012). When spraying, thoroughly wet the plant while spraying on the lower surfaces of the leaves, where the pests hide (FAO, 2012). Spraying should be done early in the morning or late in the evening when stomata are open. Hence leaves can absorb the nutrients directly as the excess falls into the soil for absorption by the roots (Nderitu, 2020).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site Description

The study consisted of two experiments that were conducted at the Horticulture Research and Teaching Field in a high tunnel at Egerton University, Njoro, Kenya. The field lies at a latitude of 0°23' S and longitude 35°35' 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).

3.2 The Test Crop

Tomato cultivar “Anna F1” seeds were sourced from a registered seed merchant in Nakuru (Meya Agri Traders Limited). Tomato seedlings were raised in a nursery bed before transplanting them into the plots. “Anna F1” (plate 3) 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).



Plate 3: Anna F1 fruits on the plant.

3.3 Acquisition of Rabbit Urine and Agrochemical

Raw and undiluted rabbit urine was acquired weekly from Kibuku Rabbit Farm in Nakuru. The rabbit urine was then diluted to the following concentrations: 100% v/v, 40% v/v, 25% v/v, 18.2% v/v and 0% v/v before spraying. The 0% v/v rabbit urine concentration was the negative control and it involved spraying plain water only on the plants. The reference product, Duduthrin 1.75EC (registration number: PCPB (CR)-0481), active ingredient: 17.5 g/L lambda cyhalothrin) was purchased from a registered agrochemical dealer in Nakuru. The reference product was diluted to make a concentration of 0.1% v/v Duduthrin 1.75EC before spraying. This was the positive control.

3.4 Experimental Procedures

The study was conducted in a randomized complete block design (RCBD) with six treatments and four replications (blocks). A space of 0.5 m was left between the blocks and the edges of the greenhouse. The distance from one block to another was 2 m. Every plot measured 2.7 m by 1.5 m (appendix 1). The three inner sides of each plot were boxed with polythene films to prevent interference between plots. The remaining side of each plot facing outside of the greenhouse was left for ventilation and for allowing whiteflies to move freely in and out of the plot (plate 4). This was done in case the rabbit urine is a repellent that drives the whiteflies away from those plots sprayed with rabbit urine. The treatments used were in form of spray concentrations and included: 0% v/v rabbit urine, 18.2% v/v rabbit urine, 25% v/v rabbit urine, 40% v/v rabbit urine, 100% v/v rabbit urine and 0.1% v/v Duduthrin 1.75EC (Table 1). The active ingredient of Duduthrin 1.75EC (registration number: PCPB(CR)-0481) is 17.5g/L lambda cyhalothrin. The six different treatments were randomly allocated to the six plots in each block. In each plot, 10 L of the respective treatment (spray) solution was applied at 7-day intervals. The total experimental area measured 34 m by 8 m (appendix 1). Tomato seedlings were transplanted at a spacing of 60 cm by 45 cm (Monsanto Africa, 2020). This translated to 21 tomato plants in each plot (7 rows with each row accommodating 3 plants). Treatment application commenced 21 days after transplanting (DAT). The sprays were applied using 20-liter knapsack sprayers.

Before transplanting, the experimental field was prepared mechanically by hand digging to break large soil clods and produce a fine tilth. Di-ammonium phosphate (D.A.P 18% N, 46% P₂O₅) fertilizer was then incorporated into the soil in every planting hole at a rate of 150kg ha⁻¹ (69kg P₂O₅ ha⁻¹) (Monsanto Africa, 2020). After transplanting of the tomato seedlings, the plots were weeded and irrigated whenever necessary.

Top dressing with calcium ammonium nitrate (CAN 27%N, 8% Ca) fertilizer was done at a rate of 200 kg ha⁻¹ (54 kg N ha⁻¹) in two equal splits during the vegetative growth stage of the plants. The first split was applied 2 weeks after transplanting. The second split was applied 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⁻¹. 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 and all the suckers pruned timely and uniformly in all plots. At about 35 cm height, the tomato plants were trained to wires running above the plants and parallel to the ground using nylon twines. Weed control was done manually by uprooting. Common cultural practices were applied uniformly to all the plots.



Plate 4: Individual plots boxed within polythene films and a wire mesh of size 6 feet by 1 inch.

Table 1: Treatment description

Treatment	Treatment description
A	0% v/v rabbit urine
B	18.2% v/v rabbit urine
C	25% v/v rabbit urine
D	40% v/v rabbit urine
E	100% v/v rabbit urine
F	0.1% v/v Duduthrin 1.75EC

3.5 Data Collection

Six sample plants from the five middle rows in each plot were randomly selected and tagged for data collection. The data were collected on the following parameters:

3.5.1 Whitefly Population

Adult whiteflies infested the tomato plants naturally. Therefore, there was no need of introducing the pests on the plants. Data collection on adult whitefly population began at 21 days after transplanting (DAT) and ended at 98 DAT. Data collection on the numbers of whitefly nymphs and eggs commenced at 42 DAT and ended at 98 DAT.

(i) Adult Whiteflies and Whitefly Nymphs Populations and Whitefly Eggs Count

The populations of adult whiteflies and numbers of whitefly nymphs and eggs were determined by physical counting. These data were taken and recorded before first treatment application and at 7-day intervals before subsequent treatment applications. Data on whitefly population were collected early in the morning before 9 a.m when the insects were less active. Six sample leaves were randomly selected from each sample plant for data collection on whitefly population. One sample leaf at the middle of the canopy of each sample plant was randomly selected for counting the number of whitefly eggs with the aid of a hand lens. These data were recorded as the number of whitefly eggs per plant. One sample leaf at the bottom of the canopy of each sample plant was

randomly selected for counting the number of whitefly nymphs with the aid of a hand lens. This data were recorded as the number of whitefly nymphs per plant. Four sample leaves at the top of the canopy of each sample plant was used in determining the number of adult whiteflies. These data were recorded as the number of adult whiteflies per plant. Data on whitefly population were also used to calculate control efficacy of the treatments.

(ii) Efficacy of the rabbit urine treatments

The efficacy of each treatment was calculated using Henderson-Hilton’s formula as follows:

$$\text{Efficacy} = \left(1 - \frac{\text{Nco before application} \times \text{Nt after application}}{\text{Nco after application} \times \text{Nt before application}}\right) \times 100 \quad \text{Equation 1}$$

where,

Nco is the number of whitefly eggs, nymphs and adults in the plots subjected to water sprays alone (negative control).

Nt is the number of whitefly eggs, nymphs and adults in the plots subjected to lambda cyhalothrin or the four different dilution levels of rabbit urine foliar sprays.

(iii) Adult Whitefly Incidence

This was calculated as a proportion of the number of sample plants infested by adult whiteflies over the total number of sample plants per plot. All sample plants infested and not infested by adult whiteflies in each plot were counted to obtain the percentage plants infested as follows:

$$\text{Whitefly infestation (\%)} = \frac{\text{Number of Sample Plants Infested}}{\text{Total Number of Sample Plants}} \times 100 \quad \text{Equation 2}$$

3.5.2 Yield and Yield Components of Tomato

(i) Number of Flowers per Plant

In each plot, flowers formed on each sample plant were counted and recorded at 7-day intervals over a period of 8 weeks. These data were recorded as the number of flowers per plant at that particular sampling day and not as a cumulative value. The collection of these data started at 49 DAT when the first sample plant in any of the plots set the first flower.

(ii) Number of Fruits per plant

Fruits formed on each sample plant in each plot were counted and recorded on at 7-day intervals over a period of 7 weeks. These data was recorded the as number of fruits formed per plant at that particular sampling day and not as a cumulative value. The collection of these data started at 56 DAT when the first sample plant in any of the plots produced the first fruit.

(iii) Fruit Number and Fruit Weight

Tomato fruits were harvested at the breaker stage in each plot once a week for six weeks after the first harvest. Harvesting began at 77 DAT and ended at 119 DAT. At each harvest, tomatoes from the sample plants in each plot were collectively counted and later weighed using a portable electronic weighing balance EK3001-JA 300g AND Company Limited. The total number and weight of tomatoes from the sample plants of each plot were divided by six to determine the number of fruits per plant (no/plant) and fruit weight in kilograms per plant (kg/plant), respectively.

(iv) Fruit Size

The diameter of each fruit was measured using a Vernier caliper (plate 5). The fruits were then categorized as small, medium and large, according to Mutisya *et al.* (2016). Small fruits had diameters of below 4 cm. Medium-sized fruits had diameters ranging from 4 cm to 6 cm. Large-sized fruits had diameters exceeding 6 cm. The data on the numbers of the different fruit sizes were not collected cumulatively but rather showed the actual numbers on that particular sampling day.

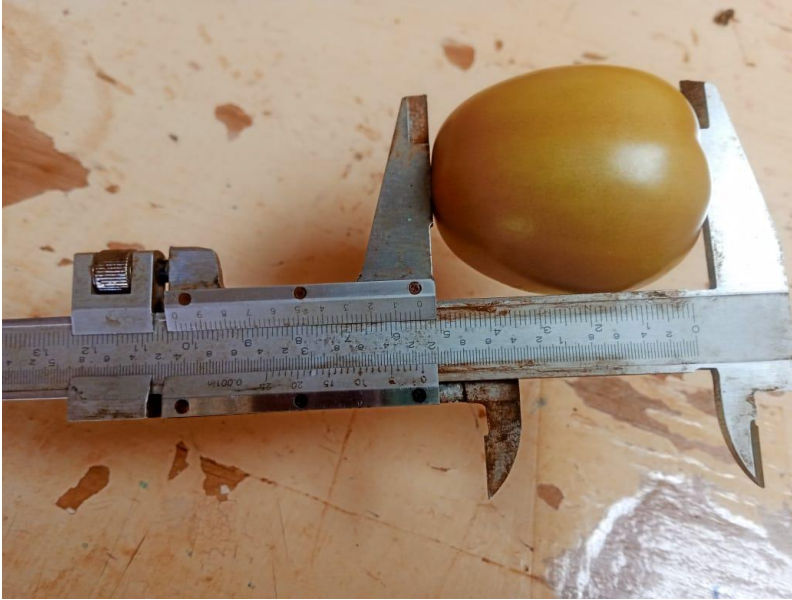


Plate 5: Measuring fruit diameter using a Vernier caliper.

(v) Marketable and Non-marketable Yields

Fruits from each plot were categorized as either being marketable or non-marketable. Marketable fruits were all fruits free from cracks, blemishes, disease infection, and other physiological disorders. Non-marketable fruits were all fruits with physical defects such as cracks and non-uniform color development, sooty mold and physiological disorders such as blossom end rot, cracks or other blemishes. Marketable and non-marketable fruits from each plot were counted and later weighed separately. The total number and weight of marketable and non-marketable fruits from each plot were separately divided by six to obtain number per plant (no/plant) and fruit weight in kilograms per plant (kg/plant), respectively (Kirimi *et al.*, 2011).

(vi) Total Yields

Both marketable and non-marketable yields were summed up every week to obtain total yield in terms of: number of fruits per plant (no/plant) and fruit weight per plant (kg/plant) from each plot. The individual harvests for each plot were later summed up after the last harvest to obtain total yields in terms of: total number of fruits per hectare (fruits ha⁻¹) and weight of marketable and non-marketable fruits (t ha⁻¹) for each plot. Both total marketable and total non-marketable yields were also summed up to

obtain the grand total yield from each treatment in terms of number of fruits per hectare (fruits ha⁻¹) and weight per hectare (t ha⁻¹).

3.5.3 Determination of Post-harvest Quality

At the third week of harvesting, 15 fruits at breaker stage from each plot were selected to determine 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 further sorted to make sure they were free from sun scorch, insect and disease damage and cracks which could otherwise affect their normal post-harvest ripening. Fruits from different plots were placed on a bench in the laboratory and changes in firmness, total soluble solids, titratable acidity and sugar acid contents of the fruits were observed over storage time of 12 days.

(a) Fruit Firmness

Fruit firmness was determined using a destructive sampling procedure involving three tomato fruits per plot per replicate starting from the first day of storage and later repeated periodically at three-day intervals for a storage period of 12 days. A hand-held penetrometer with 8 mm plunger size (model 62/DR, UK) was used to determine fruit firmness and the results were recorded in Kg Force (KgF).

(b) Total Soluble Solids (TSS) Content

The same fruits used to determine fruit firmness were used to determine total soluble solids (TSS) content. A hand-held refractometer (0-30 °Brix) (RHW Refractometer, Optoelectronic Technology Company Limited, UK) was used according to the procedure described by Majidi *et al.* (2011) and the results recorded as °Brix. This was also done at three-day intervals for a storage period of 12 days.

(c) Titratable Acidity (TA)

The same sample fruits used in TSS analysis were used in determining the titratable acidity. This was also done at three-day intervals for a storage period of 12 days. Titratable acidity was determined by the titration method explained by Al-Dairi *et al.* (2021). About 5 ml of the prepared tomato juice was diluted with 95 ml distilled water before 2-3 drops of phenolphthalein indicator are added. The titratable acidity of tomato

juice was estimated by titrating 5 ml tomato juice against 0.1 N NaOH. Titratable acidity was expressed as a percentage of citric acid and it was calculated by using the following equation:

$$\text{Citric Acid (\%)} = \frac{\text{Vol.NaOH (mL)} \times 0.1 \times 0.064}{\text{mL of juice or g of juice}} \quad \text{Equation 3}$$

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

(d) Sugar Acid Ratio

Sugar acid ratio was determined using the formula:

$$\text{Sugar : acid ratio} = \frac{\text{°Brix value}}{\text{Percentage acid}} \quad (\text{Al-Dairi } et al., 2021). \quad \text{Equation 4}$$

3.6 Data Analysis

The Proc univariate procedure of SAS (Version 9.4; SAS Institute, Cary, NC) was used to check for normality and equality of variances before analysis of variance (ANOVA) procedure. The data were then subjected to ANOVA using the GLM procedure of SAS at $P \leq 0.05$. Treatment means were separated using Tukey's honestly significant difference (THSD) test at $P \leq 0.05$. The statistical model fitted for the experiment was:

$$Y_{ijk} = \mu + \tau_i + \beta_j + \epsilon_{ijk} \quad \text{Equation 5}$$

$i = 1, 2, 3, 4, 5, 6; j = 1, 2, 3, 4$

where,

Y_{ijk} is the response from k^{th} plot receiving the i^{th} treatment in the j^{th} level block

μ - is the overall mean

τ_i - is an effect due to the i^{th} treatment

β_j - is an effect due to the j^{th} block

ϵ_{ijk} - is a random error associated with the response from the k^{th} plot receiving the i^{th} treatment in the j^{th} block.

3.7 Repellent and Toxicity Effects of Rabbit Urine on Adult Whiteflies

Two experiments on the bioactivity of rabbit urine on whiteflies were conducted. Each experiment was conducted in two trials. The first experiment was set up to determine the repellent effect of rabbit urine on adult whiteflies while the second experiment was to determine the toxic effect of rabbit urine on adult whiteflies.

3.7.1 Repellent Effect of Rabbit Urine on Adult Whiteflies

(i) Experimental Design, Layout, Treatments and Application

The experiment was conducted using a completely randomized design (CRD) with six treatments and three replications. The treatments included: 0% v/v rabbit urine (negative control), 18.2% v/v rabbit urine, 25% v/v rabbit urine, 40% v/v rabbit urine, 100% v/v rabbit urine and 0.1% v/v Duduthrin 1.75EC (positive control) as shown in Table 1 above. The active ingredient of Duduthrin 1.75EC (registration number: PCPB (CR)-0481) is 17.5g/L lambda cyhalothrin. The experimental units were cages measuring 20 cm long, 20 cm wide and 50 cm high. The distance between the cages was 1m as shown in figure 1 below. Polythene films, each 1 m high, were erected between cages due to the volatile nature of the treatments. Each cage was covered with four layers of insect-proof net to keep the whiteflies inside the cage environment. A sealable opening was fixed on the top part of each cage for the purposes of placing of potted tomato plants, watering the potted plants and data collection. One potted tomato seedling with 10 adult whiteflies was placed inside each cage through the opening. Each cage was then tightly closed immediately to allow the whiteflies settle on the potted tomato seedling for 24 hours. After 24 hours, the seedling with whiteflies in each cage was sprayed with about 20mL of the respective treatment (spray) solution. Immediately after spraying, another unsprayed potted tomato seedling with no whiteflies was placed inside each cage. The distance between the two potted tomato seedlings inside each cage was 10 cm. The whole experimental area was measuring 2.6 m by 6.2 m (figure 1). Irrigation of the seedlings was done regularly as required.

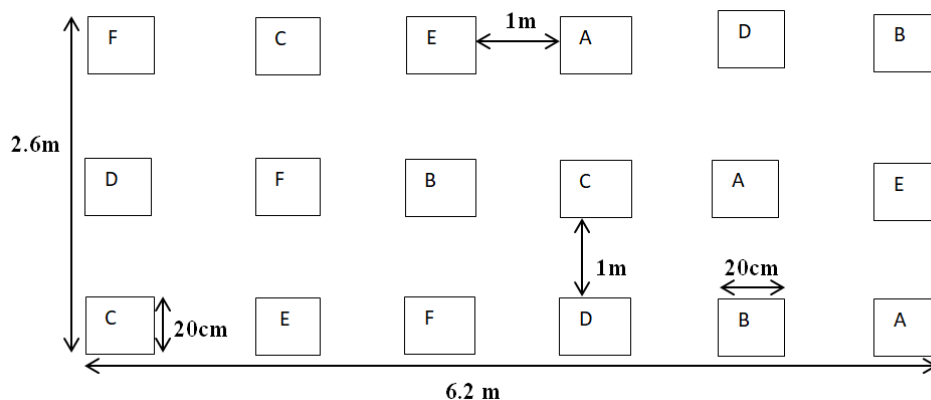


Figure 1: Experimental field layout

where, A, B, C, D, E and F are treatments as described in Table 1 above.

(ii) Data Collection

The number of adult whiteflies on the untreated (N_C) and treated (N_T) tomato seedling within each cage was recorded after 2, 12, 24 and 48 h exposure. The opening on top of each cage was closed tightly with the lid immediately after data collection to maintain a constant number of whiteflies within each cage.

(iii) Data Analysis

The raw data collected were used to compute percent repellence (PR) values according to Asawalam and Hassanali (2006):

$$PR = \frac{(N_C - N_T)}{(N_C + N_T)} \times 100 \quad \text{Equation 6}$$

Data on PR were subjected to statistical analysis using SAS Version 9.4 (SAS Institute, Cary, NC). Normality of the data was checked for analysis. Data were then subjected to ANOVA using the GLM procedure of SAS at $P \leq 0.05$. Means for significant treatments, at the F test, were separated using Tukey's honestly significant difference (THSD) test at $P \leq 0.05$. The statistical model to be fitted for this experiment will be:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij} \quad \text{Equation 7}$$

$i=1, 2, 3, 4, 5, 6$ $j=1, 2, 3$

where:

Y_{ij} is the overall observation of the i^{th} treatment in the j^{th} cage.

μ - is the overall mean,

τ_i - effect of the i^{th} treatment

ε_{ij} - random error component which is normally and independently distributed about zero mean with a common variance σ^2 .

3.7.2 Toxicity Effect of Rabbit Urine on Adult Whiteflies

(i) Experimental Design, Layout, Treatments and Application

The experiment was conducted using a completely randomized design (CRD) with six treatments and three replications. The treatments included: 0% v/v rabbit urine (negative control), 18.2% v/v rabbit urine, 25% v/v rabbit urine, 40% v/v rabbit urine, 100% v/v rabbit urine and 0.1% v/v Duduthrin 1.75EC (positive control) as shown in Table 1 above. The active ingredient of Duduthrin 1.75EC (registration number: PCPB(CR)-0481) is 17.5g/L lambda cyhalothrin. A total of 18 transparent plastic tins each with a closeable lid were used as the experimental units. Each plastic tin had a diameter of 15 cm. A 2 cm diameter hole was made at the middle of each lid for aeration to make sure that the whiteflies don't die of suffocation when the tin is sealed. The hole was then covered with a layer of insect-proof net to prevent escape of the whiteflies in the tin and entry of intruders into each tin. The distance between the tins was 30 cm. The entire experimental area measured 105 cm by 240 cm as shown in figure 2 below.

A tomato leaf with 6 adult whiteflies was inserted into each tin by slightly and carefully lifting the lid of each tin. The leaf with 6 whiteflies in each tin was sprayed directly and thoroughly with about 10mL of the respective treatment (spray) solution by slightly lifting the tin lid. Each tin was then tightly sealed immediately and the lid was slightly and carefully lifted again only during data collection.

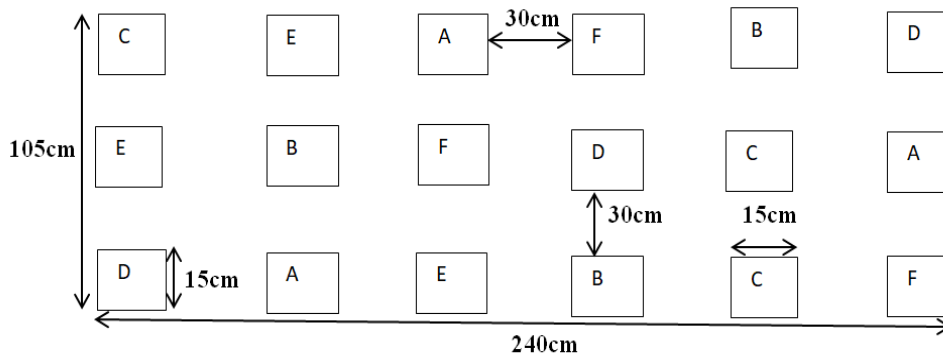


Figure 2: Laboratory experimental layout.

where, A, B, C, D, E and F are treatments as described in Table 1 above.

(iii) Data Collection

Data on the number of dead adult whiteflies inside each tin were recorded after 24, 48 and 72 h exposure. A camel brush was used to determine the number of dead adult whiteflies. An adult whitefly was declared dead if it did not make any movements after being gently disturbed using the camel brush (plate 6). These data were used to calculate percent mortality in each tin at that particular data collection time. In each tin, percent mortality was calculated using the following formula:

$$\text{Percent mortality} = \frac{\text{Number of dead adult whiteflies}}{\text{Initial total number of adult whiteflies}} \times 100$$



Plate 6: A camel brush used for data collection on adult whitefly mortality.

(iv) Data Analysis

The data on percentage mortality were further log-transformed before being subjected to probit regression analysis using SAS Version 9.4 (SAS Institute, Cary, NC). LC₅₀ values (% v/v) and the corresponding 95% fiducial limits (95% FDL) were obtained from derived regression equations (Finney, 1971; Mead *et al.*, 2003). The LC₅₀ values, in a column, were considered significantly different when 95% fiducial limits did not overlap.

CHAPTER FOUR

RESULTS

4.1 Effect of Different Concentrations of Rabbit Urine Foliar Spray on Whitefly Population

4.1.1 Adult Whitefly Population

The population of adult whiteflies was significantly influenced by rabbit urine foliar spray (table 2). In most sampling days of both trials, treatment 100% v/v rabbit urine registered significantly ($P \leq 0.05$) lower populations of adult whiteflies than treatments 0% v/v rabbit urine (negative control) and 0.1% v/v Duduthrin 1.75EC (positive control). For instance, the highest adult whitefly populations recorded from treatment 100% v/v rabbit urine after the first sprays were: 12.0 adult whiteflies per plant at 63 DAT of trial 1 and 8.4 adult whiteflies per plant at 28 DAT of in trial 2). The populations of adult whiteflies recorded in the negative control (0% v/v rabbit urine) increased over time, reaching their maxima at 98 DAT of both trials (51.1 adult whiteflies in trial 1 and 49.2 adult whiteflies per plant in trial 2). After the first spray, the positive control (0.1% v/v Duduthrin 1.75EC) registered its highest adult whitefly populations of 25.3 and 24.0 adult whiteflies per plant at 63 DAT of trial 1 and 98 DAT of trial 2, respectively. In most sampling days of both trials, the population of adult whiteflies increased with decrease in the concentration of rabbit urine foliar spray. In most sampling days of the first trial, treatment 18.2% v/v rabbit urine recorded significantly ($P \leq 0.05$) higher adult whitefly populations than treatment 100% v/v rabbit urine. In most sampling days of the second trial, treatment 100% v/v rabbit urine registered significantly ($P \leq 0.05$) lower adult whitefly populations than treatments 18.2% v/v rabbit urine, 25% v/v rabbit urine and 40% v/v rabbit urine. The populations of adult whiteflies in treatment 18.2% v/v rabbit urine were not significantly ($P \leq 0.05$) different from those recorded in treatment 0.1% v/v Duduthrin 1.75EC in most sampling days of both trials.

4.1.2 Number of Whitefly Nymphs

Use of rabbit urine foliar spray also significantly influenced the number of whitefly nymphs (table 3). In both trials, the number of whitefly nymphs decreased with increase in the concentration of rabbit urine foliar spray. In all sampling days of both

Table 2: Effect of rabbit urine foliar spray on the population of adult whiteflies per plant (no/plant) in trials 1 and 2.

Treatment	DAT											
	21	28	35	42	49	56	63	70	77	84	91	98
Trial 1												
0% v/v rabbit urine	19.8 ^a	23.2 ^a	25.1 ^a	26.9 ^a	30.3 ^a	37.6 ^a	44.1a	42.3a	42.3a	45.1a	48.4a	51.1a
18.2% v/v rabbit urine	20.4 ^a	11.4 ^b	4.8 ^b	1.9 ^b	5.4 ^b	18.2 ^b	23.0b	15.4bc	16.8bc	16.7b	15.0bc	17.2bc
25% v/v rabbit urine	20.4 ^a	10.4 ^{bc}	3.3 ^{bc}	1.2 ^b	3.8 ^b	16.9 ^b	20.0b	11.6bc	14.4bc	13.5bc	11.1cd	14.0bc
40% v/v rabbit urine	21.1 ^a	10.3 ^{bc}	3.1 ^{bc}	1.0 ^b	3.6 ^b	13.4 ^b	18.0b	11.1bc	10.9cd	11.9bc	6.8de	11.4c
100% v/v rabbit urine	20.9 ^a	8.9 ^c	2.7 ^c	0.7 ^b	2.7 ^b	9.4 ^c	12.0c	5.1c	6.8d	6.1c	3.0e	2.1d
0.1% v/v Duduthrin 1.75EC	20.8 ^a	9.9 ^{bc}	4.1 ^{bc}	2.0 ^b	6.4 ^b	18.0 ^b	25.3b	20.6b	22.4b	19.8b	20.4b	22.6b
Trial 2												
0% v/v rabbit urine	19.8 ^a	23.2 ^a	25.1 ^a	26.9 ^a	30.3 ^a	37.6 ^a	44.1a	42.3a	42.3a	45.1a	48.4a	51.1a
18.2% v/v rabbit urine	20.4 ^a	11.9 ^b	5.7 ^b	2.9 ^{bc}	6.1 ^{bc}	14.8 ^b	17.8b	16.6bc	16.3bc	15.1c	14.3c	14.5c
25% v/v rabbit urine	20.9 ^a	11.2 ^b	4.6 ^{bc}	2.0 ^{bcd}	4.2 ^{cd}	12.5 ^{bc}	15.6b	13.9cd	13.0cd	12.1cd	11.4cd	11.1cd
40% v/v rabbit urine	20.6 ^a	10.3 ^b	3.9 ^{cd}	1.3 ^{cd}	3.8 ^{cd}	9.6 ^{cd}	13.6b	11.6d	10.8d	9.9d	9.3d	9.1d
100% v/v rabbit urine	20.8 ^a	8.4 ^c	2.9 ^d	0.8 ^d	3.3 ^d	6.3 ^d	7.4c	6.6e	5.8e	4.4e	4.0e	3.2e
0.1% v/v Duduthrin 1.75EC	20.8 ^a	11.2 ^b	5.3 ^b	3.3 ^b	7.6 ^b	15.2 ^b	18.8b	19.8b	19.9b	22.2b	23.1b	24.0b

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

trials, treatment 100% v/v rabbit urine registered significantly ($P \leq 0.05$) lower numbers of whitefly nymphs than all the other treatments. In both trials, the numbers of whitefly nymphs recorded in treatment 100% v/v rabbit urine decreased over time, reaching their minimums at 98 DAT (13.0 whitefly nymphs per plant in trial 1 and 13.1 whitefly nymphs per plant in trial 2). Likewise, the numbers of whitefly nymphs recorded in treatments 25% v/v rabbit urine and 40% v/v rabbit urine decreased over time from 42 DAT to reach their minimums at 98 DAT. On the other hand, treatment 0% v/v rabbit urine (negative control) registered significantly ($P \leq 0.05$) higher numbers of whitefly nymphs than all other treatments in most sampling days of both trials. The numbers of whitefly nymphs recorded in treatment 0% v/v rabbit urine increased over time to reach their maximums at 98 DAT of both trials (166.8 whitefly nymphs per plant in trial 1 and 125.2 whitefly nymphs per plant in trial 2). The numbers of whitefly nymphs recorded in treatments 100% v/v rabbit urine, 40% v/v rabbit urine and 25% v/v rabbit urine decreased over time from 42 DAT of both trials to reach their maximums in 98 DAT of both trials. In trial 1, treatment 0.1% v/v Duduthrin 1.75EC exhibited a decreasing trend in whitefly nymph number over time from 42 DAT up to 70 DAT, after which the trend turned into an increasing one to reach its maximum at 98 DAT (104.0 whitefly nymphs per plant). In trial 2, the number of whitefly nymphs in treatment 0.1% v/v Duduthrin 1.75EC decreased over time from 42 DAT up to 56 DAT, after which the number started to decrease over time, reaching its maximum at 98 DAT (98.9 whitefly nymphs per plant).

4.1.3 Number of Whitefly Eggs

There were significant differences among treatments as affected by the different concentrations of rabbit urine foliar spray (table 4). In most sampling weeks of both trials, the number of whitefly eggs per plant increased with decrease in the concentration of rabbit urine foliar spray. Treatment 100% v/v rabbit urine registered significantly ($P \leq 0.05$) the least number of whitefly eggs per plant while treatment 0% v/v rabbit urine recorded significantly ($P \leq 0.05$) the greatest in all sampling days of both trials. In both trials, the number of whitefly eggs per plant registered in treatment 100% v/v rabbit urine decreased over time from 42 DAT to record the least at 98 DAT (11.0 and 16.5 whitefly eggs per plant in trials 1 and 2, respectively). Likewise, the number of whitefly eggs

Table 3: Effect of rabbit urine foliar spray on the population of whitefly nymphs per plant (no/plant) in trials 1 and 2.

Treatment	DAT								
	42	49	56	63	70	77	84	91	98
Trial 1									
0% v/v rabbit urine	122.0 ^a	129.7 ^a	133.5 ^a	138.6 ^a	142.4 ^a	149.7 ^a	159.1 ^a	162.7 ^a	166.8 ^a
18.2% v/v rabbit urine	111.8 ^{ab}	114.2 ^{ab}	114.3 ^b	113.3 ^b	113.3 ^b	110.0 ^b	110.6 ^b	113.1 ^b	113.1 ^b
25% v/v rabbit urine	98.3 ^{bc}	97.3 ^{bc}	96.3 ^c	95.1 ^{bc}	89.5 ^{cd}	84.3 ^{cd}	80.2 ^c	76.21 ^c	71.8 ^c
40% v/v rabbit urine	89.9 ^c	88.3 ^c	86.1 ^c	80.9 ^c	72.0 ^d	65.1 ^d	60.2 ^d	53.7 ^d	49.0 ^d
100% v/v rabbit urine	41.7 ^d	38.5 ^d	34.0 ^d	32.8 ^d	28.5 ^e	23.1 ^e	21.0 ^e	16.5 ^e	13.0 ^e
0.1% v/v Duduthrin 1.75EC	98.3 ^{bc}	98.0 ^{bc}	95.7 ^c	96.7 ^{bc}	96.3 ^{bc}	96.7 ^{bc}	97.6 ^b	100.0 ^b	104.0 ^b
Trial 2									
0% v/v rabbit urine	101.8 ^a	105.1 ^a	107.8 ^a	110.7 ^a	113.8 ^a	117.4 ^a	120.4 ^a	123.8 ^a	125.2 ^a
18.2% v/v rabbit urine	98.4 ^{ab}	98.0 ^a	98.1 ^b	97.4 ^b	94.5 ^b	93.8 ^b	93.1 ^b	91.1 ^c	89.0 ^c
25% v/v rabbit urine	92.3 ^b	90.8 ^b	88.0 ^c	85.8 ^c	85.1 ^c	82.4 ^c	80.8 ^c	78.5 ^d	75.0 ^d
40% v/v rabbit urine	78.5 ^c	74.9 ^c	72.0 ^d	68.8 ^d	64.6 ^d	59.9 ^d	55.4 ^d	52.6 ^e	48.3 ^e
100% v/v rabbit urine	41.2 ^d	37.3 ^d	33.9 ^e	30.0 ^e	26.5 ^e	22.6 ^e	19.3 ^e	16.4 ^f	13.1 ^f
0.1% v/v Duduthrin 1.75EC	92.7 ^b	90.3 ^b	89.4 ^c	91.7 ^{bc}	94.2 ^b	96.5 ^b	98.9 ^b	99.5 ^b	98.9 ^b

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

Table 4: Effect of rabbit urine foliar spray on the number of whitefly eggs per plant (no/plant) in trials 1 and 2.

Treatment	DAT								
	42	49	56	63	70	77	84	91	98
Trial 1									
0% v/v rabbit urine	165.6 ^a	175.0 ^a	176.4 ^a	180.1 ^a	183.2 ^a	185.3 ^a	187.1 ^a	190.5 ^a	192.6 ^a
18.2% v/v rabbit urine	121.4 ^b	119.9 ^b	118.4 ^b	115.9 ^b	114.13 ^b	116.1 ^b	118.6 ^b	122.1 ^b	126.3 ^b
25% v/v rabbit urine	94.8 ^c	91.3 ^c	88.8 ^c	86.5 ^c	81.8 ^c	78.5 ^c	74.1 ^c	68.3 ^c	61.8 ^c
40% v/v rabbit urine	84.2 ^d	78.3 ^d	74.1 ^d	68.6 ^d	63.4 ^d	59.1 ^d	51.5 ^d	44.1 ^d	38.0 ^d
100% v/v rabbit urine	49.7 ^e	44.5 ^e	36.5 ^e	31.1 ^e	26.8 ^e	22.7 ^e	18.0 ^e	15.8 ^e	11.0 ^e
0.1% v/v Duduthrin 1.75EC	100.6 ^c	94.9 ^c	91.3 ^c	88.3 ^c	89.5 ^c	93.0 ^c	98.3 ^b	102.5 ^b	107.2 ^b
Trial 2									
0% v/v rabbit urine	118.1 ^a	121.4 ^a	123.5 ^a	126.3 ^a	129.8 ^a	133.2 ^a	135.4 ^a	138.3 ^a	141.6 ^a
18.2% v/v rabbit urine	113.8 ^a	110.5 ^b	110.2 ^b	109.5 ^b	107.2 ^b	104.0 ^b	101.8 ^{bc}	99.9 ^b	97.6 ^c
25% v/v rabbit urine	107.4 ^b	105.5 ^{bc}	103.2 ^{bc}	101.1 ^{bc}	97.7 ^b	94.9 ^c	93.9 ^c	90.4 ^c	88.3 ^d
40% v/v rabbit urine	97.4 ^c	95.3 ^d	91.8 ^d	88.2 ^d	84.6 ^c	80.7 ^d	77.5 ^d	73.4 ^d	70.3 ^e
100% v/v rabbit urine	55.3 ^d	51.0 ^e	46.2 ^e	42.1 ^e	35.6 ^d	30.6 ^e	26.7 ^e	21.0 ^e	16.5 ^f
0.1% v/v Duduthrin 1.75EC	106.9 ^b	102.5 ^{cd}	97.5 ^{cd}	97.3 ^c	99.5 ^b	102.5 ^{bc}	104.4 ^b	106.8 ^b	108.4 ^b

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

recorded in treatments 25% v/v rabbit urine and 40% v/v rabbit urine decreased over time from 42 DAT to reach their minimums at 98 DAT. However, the number of whitefly eggs per plant registered in treatment 0% v/v rabbit urine (negative control) increased over time from 42 DAT to record the highest at 98 DAT (192.6 and 141.6 whitefly eggs per plant in trials 1 and 2, respectively). In most sampling days of both trials, there were no significant ($P \leq 0.05$) differences between treatments 25% v/v rabbit urine and 0.1% v/v Duduthrin 1.75EC in the number of whitefly eggs per plant. The number of whitefly eggs recorded in treatment 0.1% v/v Duduthrin 1.75EC decreased over time from 21 DAT to 63 DAT, after which it started to increase over time to reach their maximums at 98 DAT (107.2 and 108.4 whitefly eggs per plant in trials 1 and 2, respectively).

4.1.4 Efficacy of Rabbit Urine against Adult Whiteflies

Results showed that rabbit urine foliar spray had significant concentration-dependent efficacy against adult whiteflies (table 5). In all sampling days of both trials, the efficacy of rabbit urine against adult whiteflies increased with increase in the concentration of rabbit urine foliar spray. Treatment 100% v/v rabbit urine recorded the highest efficacy against adult whiteflies at 35 DAT of both trials (97.1% and 97.4% in trials 1 and 2, respectively). In most sampling days of both trials, the efficacy of treatment 100% v/v rabbit urine against adult whiteflies was significantly ($P \leq 0.05$) higher than that of treatment 0.1% v/v Duduthrin 1.75EC (positive control). Treatment 0.1% v/v Duduthrin 1.75EC recorded the lowest efficacies against adult whiteflies of 45.0% at 56 DAT of trial 1 and 50.6% at 98 DAT of trial 2. During the first trial, the efficacy of treatment 0.1% v/v Duduthrin 1.75EC against adult whiteflies was not significantly ($P \leq 0.05$) different from those of treatments 18.2% v/v rabbit urine, 25% v/v rabbit urine and 40% v/v rabbit urine in most sampling days. In most sampling days of the second trial, the efficacy of treatment 0.1% v/v Duduthrin 1.75EC against adult whiteflies was significantly ($P \leq 0.05$) lower than those recorded in treatments 25% v/v rabbit urine and 40% v/v rabbit urine.

4.1.5 Efficacy of Rabbit Urine against Whitefly Nymphs

Rabbit urine foliar spray had significant concentration-dependent efficacy against whitefly nymphs (table 6). In both trials, the efficacy of each treatment against whitefly

nymphs increased over time from 42 DAT to reach its maximum at 91 DAT. In all sampling days of both trials, the efficacy of rabbit urine against whitefly nymphs increased with increase in the concentration of rabbit urine foliar spray. Treatment 100% v/v rabbit urine recorded the highest efficacy against adult whiteflies at 91 DAT of both trials (77.3% and 74.0% in trials 1 and 2, respectively). In most sampling days of both trials, the efficacy of treatment 0.1% v/v Duduthrin 1.75EC against whitefly nymphs was significantly ($P \leq 0.05$) lower than those of treatments 25% v/v rabbit urine, 40% v/v rabbit urine 100% v/v rabbit urine. However, in most sampling days of trial 1, there were no significant ($P \leq 0.05$) differences between the efficacies of treatment 0.1% v/v Duduthrin 1.75EC against whitefly nymphs and those of treatment 18.2% v/v rabbit urine. However, in the second half of the trial 2, the efficacy of treatment 0.1% v/v Duduthrin 1.75EC against whitefly nymphs was significantly ($P \leq 0.05$) lower than that of treatment 18.2% v/v rabbit urine.

4.1.6 Efficacy of Rabbit Urine against Whitefly Eggs

The efficacies of different concentrations of rabbit urine foliar spray against whitefly eggs varied significantly (table 7). In both trials, the efficacy of rabbit urine against whitefly eggs increased with increase in the concentration of rabbit urine foliar spray. Treatment 100% v/v rabbit urine registered significantly ($P \leq 0.05$) higher efficacies against whitefly eggs than all the other treatments. In both trials, treatment 100% v/v rabbit urine recorded the highest efficacies against whitefly eggs at 91 DAT (81.8% and 78.4% in trials 1 and 2, respectively). The efficacies of treatments 25% v/v rabbit urine, 40% v/v rabbit urine and 100% v/v rabbit urine against whitefly eggs increased over time to reach their maxima at 91 DAT of both trials. In both trials, the efficacies of treatment 0.1% v/v Duduthrin 1.75EC against whitefly eggs increased over time up to 63 DAT, after which the efficacies began to decline to reach 8.4% and 15.4% at 91 DAT of trials 1 and 2, respectively. Although treatment 18.2% v/v rabbit urine recorded lower efficacies against whitefly eggs than treatment 0.1% v/v Duduthrin 1.75EC at 42 DAT of both trials, treatment 18.2% v/v rabbit urine ended up registering higher efficacies than treatment 0.1% v/v Duduthrin 1.75EC at 91 DAT of both trials.

Table 5: Efficacy of rabbit urine foliar spray against adult whiteflies in trials 1 and 2.

Treatment	DAT										
	21	28	35	42	49	56	63	70	77	84	91
Trial 1											
18.2% v/v rabbit urine	52.2 ^b	81.1 ^c	92.3 ^a	82.2 ^a	51.1 ^b	50.3 ^b	61.9 ^{ab}	59.3 ^{bc}	62.3 ^b	69.0 ^{cd}	67.4 ^{bc}
25% v/v rabbit urine	56.8 ^{ab}	87.0 ^{ab}	95.3 ^a	88.2 ^a	53.7 ^b	56.0 ^{ab}	71.0 ^{ab}	65.2 ^{ab}	70.0 ^{ab}	76.2 ^{bc}	73.3 ^b
40% v/v rabbit urine	57.9 ^{ab}	88.3 ^{ab}	96.7 ^a	88.3 ^a	64.5 ^{ab}	61.9 ^{ab}	73.9 ^{ab}	74.5 ^{ab}	73.3 ^{ab}	85.9 ^{ab}	78.8 ^b
100% v/v rabbit urine	63.1 ^a	89.0 ^a	97.4 ^a	90.9 ^a	72.4 ^a	73.8 ^a	86.8 ^a	83.4 ^a	85.2 ^a	93.4 ^a	95.3 ^a
0.1% v/v Duduthrin 1.75EC	59.2 ^{ab}	83.8 ^{bc}	91.9 ^a	77.4 ^a	52.9 ^b	45.0 ^b	46.6 ^b	46.4 ^c	54.8 ^b	57.9 ^d	56.7 ^c
Trial 2											
18.2% v/v rabbit urine	49.0 ^c	77.9 ^c	90.0 ^{ab}	80.8 ^{ab}	59.7 ^c	55.3 ^b	60.0 ^{cd}	62.6 ^{cd}	65.9 ^b	68.6 ^b	69.5 ^b
25% v/v rabbit urine	52.7 ^{bc}	82.5 ^{bc}	93.4 ^{ab}	87.1 ^a	67.1 ^{bc}	61.8 ^b	67.5 ^{bc}	71.1 ^{bc}	73.4 ^b	75.7 ^b	77.3 ^b
40% v/v rabbit urine	56.1 ^{ab}	85.1 ^{ab}	95.6 ^{ab}	88.8 ^a	74.6 ^{ab}	67.1 ^{ab}	73.1 ^{ab}	75.8 ^{ab}	78.2 ^{ab}	80.3 ^{ab}	81.5 ^{ab}
100% v/v rabbit urine	63.2 ^a	88.5 ^a	97.1 ^a	89.2 ^a	82.5 ^a	81.0 ^a	83.9 ^a	86.5 ^a	90.0 ^a	91.1 ^a	93.2 ^a
0.1% v/v Duduthrin 1.75EC	53.3 ^{bc}	81.8 ^{bc}	88.5 ^b	76.1 ^b	59.3 ^c	53.6 ^b	53.4 ^d	55.3 ^d	51.1 ^c	50.1 ^c	50.6 ^c

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

Table 6: Efficacy of rabbit urine foliar spray against whitefly nymphs in trials 1 and 2.

Treatment	DAT							
	42	49	56	63	70	77	84	91
Trial 1								
18.2% v/v rabbit urine	3.9 ^b	6.6 ^b	10.8 ^c	13.2 ^c	19.8 _c	23.9 _c	23.9 ^d	25.9 ^d
25% v/v rabbit urine	7.0 ^{ab}	10.4 ^b	15.0 ^{bc}	22.2 ^{bc}	30.1 _{bc}	37.2 _b	41.7 ^c	46.6 ^c
40% v/v rabbit urine	7.8 ^{ab}	12.5 ^b	20.9 ^b	31.4 ^{ab}	41.0 _b	48.5 ^{ab}	55.2 ^b	60.2 ^b
100% v/v rabbit urine	13.4 ^a	25.5 ^a	30.9 ^a	41.6 ^a	55.0 _a	61.2 _a	70.2 ^a	77.3 ^a
0.1% v/v Duduthrin 1.75EC	6.3 ^b	11.0 ^b	13.5 ^{bc}	16.1 ^c	19.6 _c	22.9 _c	22.9 ^d	22.2 ^d
Trial 2								
18.2% v/v rabbit urine	3.5 ^c	5.7 ^b	8.9 ^d	14.0 ^{cd}	17.3 _c	19.8 _c	23.9 ^c	26.4 ^d
25% v/v rabbit urine	4.7 ^{bc}	11.4 ^b	14.4 ^c	17.4 ^c	22.5 _c	25.9 _c	30.0 ^c	33.9 ^c
40% v/v rabbit urine	7.5 ^b	11.7 ^b	19.2 ^b	26.2 ^b	33.7 _b	40.2 _b	44.9 ^b	49.9 ^b
100% v/v rabbit urine	12.4 ^a	22.2 ^a	32.9 ^a	42.6 ^a	52.5 _a	60.3 _a	67.1 ^a	74.0 ^a
0.1% v/v Duduthrin 1.75EC	5.7 ^{bc}	8.8 ^b	9.0 ^d	9.0 ^d	9.6 _d	9.6 _d	11.7 ^d	13.2 ^e

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

Table 7: Efficacy of rabbit urine foliar spray against whitefly eggs in trials 1 and 2.

Treatment	DAT							
	42	49	56	63	70	77	84	91
Trial 1								
18.2% v/v rabbit urine	6.4 ^b	8.4 ^b	12.0 ^b	15.0 ^c	14.4 ^c	13.6 ^d	12.5 ^d	10.8 ^d
25% v/v rabbit urine	8.8 ^{ab}	11.2 ^b	16.1 ^b	22.1 ^{bc}	26.0 ^{bc}	31.0 ^c	37.6 ^c	44.1 ^c
40% v/v rabbit urine	11.9 ^{ab}	17.5 ^b	25.5 ^b	32.4 ^b	37.7 ^b	46.6 ^b	55.1 ^b	61.9 ^b
100% v/v rabbit urine	15.2 ^a	32.0 ^a	43.6 ^a	52.2 ^a	60.6 ^a	69.4 ^a	73.6 ^a	81.8 ^a
0.1% v/v Duduthrin 1.75EC	10.6 ^{ab}	14.9 ^b	19.4 ^b	19.2 ^{bc}	17.5 ^c	13.8 ^d	11.4 ^d	8.4 ^d
Trial 2								
18.2% v/v rabbit urine	5.4 ^{ab}	6.8 ^b	9.8 ^b	14.3 ^b	18.9 ^{cd}	21.9 ^c	25.0 ^c	28.4 ^c
25% v/v rabbit urine	4.4 ^b	8.1 ^b	11.9 ^b	17.3 ^b	21.0 ^{bc}	23.6 ^c	28.1 ^c	31.4 ^c
40% v/v rabbit urine	4.8 ^b	9.8 ^{ab}	15.2 ^b	20.9 ^b	26.0 ^b	30.6 ^b	35.6 ^b	39.8 ^b
100% v/v rabbit urine	10.2 ^a	20.1 ^a	28.7 ^a	41.5 ^a	51.0 ^a	57.9 ^a	67.6 ^a	78.4 ^a
0.1% v/v Duduthrin 1.75EC	6.7 ^{ab}	12.8 ^b	14.8 ^b	15.1 ^b	15.0 ^d	14.8 ^d	14.7 ^d	15.4 ^d

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

4.1.7 Effect of Rabbit Urine on Adult Whitefly Incidence

The adult whitefly incidence was influenced significantly by different concentrations of rabbit urine foliar spray (table 8). In most sampling days of both trials, the adult whitefly incidence was highest in treatment 0% rabbit urine (negative control) but lowest in treatment 100% rabbit urine. Of all the treatments, treatment 100% v/v rabbit urine recorded the lowest adult whitefly incidence of 52.2% at 77 DAT of trial 1 and 50.4% at 98 DAT of trial 2. The adult whitefly incidence of treatment 0.1% v/v Duduthrin 1.75EC exhibited a declining trend in the first two sampling days of both trials, after which the incidence increased drastically to reach and settle at 100.0% from 35 DAT to 98 DAT of both trials.

4.2 Repellent and Toxic Effects of Rabbit Urine on Adult Whiteflies

4.2.1 Repellent Effect of Rabbit Urine on Adult Whiteflies

Rabbit urine spray had significant concentration-dependent effect on the repellence of adult whiteflies (table 9). In both trials, percent repellence (PR) increased with increase in the concentration of rabbit urine spray. Treatment 100% v/v rabbit urine recorded the highest repellence, with 100.00% being its highest PR value from 12 h to 48 h after exposure in both trials. In both trials, treatment 0% v/v rabbit urine registered the lowest PR value of 0.00% in all sampling hours of both trials. In both trials, the PR values in treatment 100% v/v rabbit urine were significantly ($P \leq 0.05$) higher than those in treatment 0% v/v rabbit urine. However, the PR values in treatment 0.1% v/v Duduthrin 1.75EC were not significantly ($P \leq 0.05$) different from those in treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine in both trials.

4.2.2 Toxic Effect of Rabbit Urine on Adult Whiteflies

The study results showed that the toxicity effect of rabbit urine on adult whiteflies was not significantly different from that of Duduthrin 1.75EC (table 10). In both trials, the LC_{50} values of rabbit urine alone and those of rabbit urine + Duduthrin decreased over time with increase in exposure time from 24 h to 72 h. At 24 h after exposure, the LC_{50} values of rabbit urine (165.96% v/v in trial 1 and 165.96% v/v in trial 2) were lower than those in rabbit urine + Dududthrin (1949.84% v/v in trial 1 and 1348.96% v/v in trial 2). However, there were no significant ($P \leq 0.05$) differences between the two in both trials

Table 8: Effect of rabbit urine foliar spray on adult whitefly incidence (%) in trials 1 and 2.

Treatment	DAT											
	21	28	35	42	49	56	63	70	77	84	91	98
Trial 1												
0% v/v rabbit urine	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a
18.2% v/v rabbit urine	100.0 ^a	100.0 ^a	100.0 ^a	87.5 ^a	100.0 ^a	100.0 ^a	100.0 ^a	91.2 ^a	86.3 ^{ab}	100.0 ^a	100.0 ^a	100.0 ^a
25% v/v rabbit urine	100.0 ^a	100.0 ^a	95.8 ^a	79.2 ^a	100.0 ^a	100.0 ^a	100.0 ^a	86.3 ^{ab}	86.3 ^{ab}	100.0 ^a	100.0 ^a	100.0 ^a
40% v/v rabbit urine	100.0 ^a	100.0 ^a	100.0 ^a	75.0 ^{ab}	100.0 ^a	100.0 ^a	100.0 ^a	86.3 ^{ab}	69.4 ^{ab}	100.0 ^a	100.0 ^a	100.0 ^a
100% v/v rabbit urine	100.0 ^a	100.0 ^a	91.7 ^a	53.7 ^b	74.5 ^b	95.8 ^a	100.0 ^a	69.4 ^b	52.2 ^b	91.2 ^a	72.6 ^b	52.7 ^b
0.1% v/v Duduthrin 1.75EC	92.4 ^a	82.7 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a
Trial 2												
0% v/v rabbit urine	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a
18.2% v/v rabbit urine	100.0 ^a	100.0 ^a	100.0 ^a	82.5 ^a	100.0 ^a	95.5 ^a	100.0 ^a	91.7 ^a	87.5 ^a	95.8 ^a	100.0 ^a	100.0 ^a
25% v/v rabbit urine	100.0 ^a	100.0 ^a	100.0 ^a	78.8 ^a	100.0 ^a	95.5 ^a	100.0 ^a	87.5 ^a	87.5 ^a	95.8 ^a	100.0 ^a	95.8 ^a
40% v/v rabbit urine	100.0 ^a	100.0 ^a	95.5 ^{ab}	73.7 ^{ab}	95.5 ^a	95.5 ^a	100.0 ^a	87.5 ^a	78.2 ^{ab}	100.0 ^a	95.8 ^a	95.8 ^a
100% v/v rabbit urine	91.7 ^a	95.2 ^a	87.2 ^b	53.7 ^b	74.5 ^b	74.5 ^b	82.5 ^b	55.6 ^b	62.5 ^b	74.5 ^b	62.7 ^b	50.4 ^b
0.1% v/v Duduthrin 1.75EC	96.8 ^a	95.2 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a	100.0 ^a

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

Table 9: Repellent effect of rabbit urine foliar spray on adult whiteflies (percent repellence) in trials 1 and 2.

Treatment	Exposure Time (Hours) after treatment			
	2	12	24	48
Trial 1				
0% v/v rabbit urine	0.00 ^c	0.00 ^d	0.00 ^e	0.00 ^e
18.2% v/v rabbit urine	46.67 ^b	53.33 ^c	53.33 ^d	53.33 ^d
25% v/v rabbit urine	66.67 ^{ab}	73.33 ^{bc}	73.33 ^{bc}	73.33 ^{bc}
40% v/v rabbit urine	73.33 ^{ab}	80.00 ^{ab}	80.00 ^b	80.00 ^b
100% v/v rabbit urine	93.33 ^a	100.00 ^a	100.00 ^a	100.00 ^a
0.1% v/v Duduthrin 1.75EC	46.67 ^b	53.33 ^c	60.00 ^{cd}	60.00 ^{cd}
Trial 2				
0% v/v rabbit urine	0.00 ^c	0.00 ^d	0.00 ^d	0.00 ^e
18.2% v/v rabbit urine	53.33 ^b	60.00 ^b	53.33 ^c	53.33 ^d
25% v/v rabbit urine	73.33 ^{ab}	86.67 ^{ab}	80.00 ^b	73.33 ^{bc}
40% v/v rabbit urine	80.00 ^{ab}	86.67 ^{ab}	80.00 ^b	80.00 ^b
100% v/v rabbit urine	93.33 ^a	100.00 ^a	100.00 ^a	100.00 ^a
0.1% v/v Duduthrin 1.75EC	73.33 ^{ab}	73.33 ^{ab}	60.00 ^{bc}	60.00 ^{cd}

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

since the respective 95% FDLs were overlapping. At 72 h after exposure in both trials, the LC_{50} values of rabbit urine (4.79% v/v in trial 1 and 5.50% v/v in trial 2) were higher than those in rabbit urine + Dududthrin (0.02% v/v in trial 1 and 0.02% v/v in trial 2).

4.3 Effect of Rabbit Urine Foliar Spray on Yield and Yield Components of Tomato

4.3.1 Number of Flowers Formed per Plant

Results showed that rabbit urine foliar spray had significant concentration-dependent effect on the number of flowers formed per plant (Table 11). In most sampling days of both trials, the number of flowers formed per plant increased with increase in the concentration of rabbit urine foliar spray from 0% v/v up to 40% v/v concentration.

Table 10: Toxic effect of rabbit urine foliar spray on adult whiteflies (LC₅₀ (% v/v)) in trials 1 and 2.

Treatments	Exposure Time (Hours) after treatment					
	24		48		72	
	LC50	95% FDL	LC50	95% FDL	LC50	95% FDL
Trial 1						
Rabbit urine	165.96	(0.33 , 0.83)	81.28	(0.15 , 0.95)	4.79	(0.01 , 0.93)
Rabbit urine + Duduthrin 1.75EC	1949.84	(-0.49 , 0.92)	275.42	(-0.60 , 0.96)	0.02	(-0.65 , 0.90)
Trial 2						
Rabbit urine	165.96	(0.46 , 0.73)	81.28	(0.19 , 0.96)	5.50	(-0.03 , 1.03)
Rabbit urine + Duduthrin 1.75EC	1348.96	(-0.46 , 0.92)	213.80	(-0.55 , 0.92)	0.02	(-0.57 , 0.83)

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

However, increasing the rabbit urine foliar spray concentration from 40% v/v to 100% v/v reduced the number of flowers formed per plant. The number of flowers in treatments 18.2% v/v rabbit urine, 25% v/v rabbit urine and 100% v/v rabbit urine increased over time from 49 DAT to reach their maximums at 77 DAT of both trials, after which the number of flowers in these treatments started to decline. In most sampling days of both trials, the number of flowers in treatment 100% v/v rabbit urine was lower than those of all other treatments. The least number of flowers formed per plant was recorded in treatment 0% v/v rabbit urine at 49 DAT of both trials (3.79 and 3.46 flowers per plant in trials 1 and 2, respectively). Treatment 40% v/v rabbit urine registered the highest number of flowers formed per plant at 77 DAT of both trials (21.63 and 22.42 flowers per plant in trials 1 and 2, respectively). The number of flowers formed in treatments 0% v/v rabbit urine and 0.1% v/v Duduthrin 1.75EC reached their maximums at 84 DAT of both trials,

after which the number of flowers in these treatments started to decline.

4.3.2 Number of Fruits per Plant

Rabbit urine foliar spray had significant concentration-dependent effect on the number of fruits formed per plant (Table 12). In most sampling days of trial 1, the number of fruits formed per plant increased with increase in the concentration of rabbit urine from 0% v/v to 100% v/v. In most sampling days of trial 2, the number of fruits formed per plant increased with increase in the concentration of rabbit urine from 0% v/v to 25% v/v, after which the numbers started to decline. In most sampling days of the first trial, the number of fruits formed in treatment 100% v/v rabbit urine were significantly ($P \leq 0.05$) higher than those recorded in the other treatments. However, in most sampling days of the second trial, the number of fruits formed in treatment 100% v/v rabbit urine were significantly ($P \leq 0.05$) lower than those recorded in the other treatments. There were no significant ($P \leq 0.05$) differences among the numbers of fruits formed per plant in treatments 18.2% v/v rabbit urine, 25% v/v rabbit urine, 40% v/v rabbit urine and 0.1% v/v Duduthrin 1.75EC in all sampling days of both trials. In both trials, the number of fruits formed increased over time from 56 DAT to reach their maxima at 105 DAT. At 105 DAT of both trials, treatment 25% v/v rabbit urine recorded the highest number of fruits per plant (35.63 and 33.96 fruits formed per plant in trials 1 and 2, respectively). In the first four sampling days of trial 1 and first two sampling days of trial 2, the number of fruits formed per plant in treatment 100% v/v rabbit urine was significantly ($P \leq 0.05$) higher than that recorded in treatment 0% v/v rabbit urine (negative control).

4.3.3 Fruit Size

(a) Number of Small-sized Fruits (diameter: <4 cm)

Rabbit urine foliar spray had an effect on the number of small fruits harvested per plant (table 13). In most sampling days of both trials, the number of small fruits decreased with decrease in the concentration of rabbit urine foliar spray from 100% v/v to 18.2% v/v. Decreasing rabbit urine foliar spray concentration from 18.2% v/v to 0% v/v increased the number of small fruits harvested per plant in most sampling days of both trials. Treatment 0% v/v rabbit urine (negative control) recorded the highest numbers of

Table 11: Effect of rabbit urine foliar spray on the number of flowers per plant (no/plant) in trials 1 and 2.

Treatment	DAT								
	49	56	63	70	77	84	91	98	105
Trial 1									
0% v/v rabbit urine	3.79 ^a	7.67 ^a	15.04 ^a	19.42 ^{ab}	19.21 ^{ab}	19.29 ^a	16.75 ^a	15.50 ^a	13.04 ^{ab}
18.2% v/v rabbit urine	4.21 ^a	8.88 ^a	15.24 ^a	20.04 ^{ab}	20.54 ^{ab}	19.96 ^a	18.80 ^a	16.79 ^a	16.17 ^{ab}
25% v/v rabbit urine	4.54 ^a	9.67 ^a	17.37 ^a	21.08 ^{ab}	21.09 ^a	20.46 ^a	20.79 ^a	17.25 ^a	16.46 ^a
40% v/v rabbit urine	4.96 ^a	10.21 ^a	18.41 ^a	21.52 ^a	21.63 ^a	20.96 ^a	20.83 ^a	18.08 ^a	17.13 ^{ab}
100% v/v rabbit urine	3.88 ^a	8.00 ^a	14.71 ^a	15.21 ^b	17.84 ^b	17.54 ^a	16.21 ^a	14.83 ^a	12.63 ^b
0.1% v/v Duduthrin 1.75EC	4.92 ^a	9.79 ^a	15.92 ^a	18.42 ^{ab}	19.58 ^{ab}	19.79 ^a	18.33 ^a	17.84 ^a	16.84 ^a
Trial 2									
0% v/v rabbit urine	3.46 ^a	7.71 ^a	12.46 ^a	16.13 ^{bc}	18.21 ^a	19.54 ^a	16.88 ^{ab}	16.42 ^a	14.88 ^a
18.2% v/v rabbit urine	4.17 ^a	9.00 ^a	14.24 ^a	19.17 ^{ab}	20.63 ^a	20.50 ^a	18.30 ^a	16.50 ^a	16.29 ^a
25% v/v rabbit urine	4.67 ^a	9.46 ^a	16.13 ^a	19.42 ^{ab}	21.13 ^a	21.04 ^a	20.04 ^a	17.00 ^a	16.59 ^a
40% v/v rabbit urine	5.00 ^a	10.27 ^a	16.91 ^a	21.38 ^a	22.42 ^a	21.88 ^a	20.46 ^a	19.25 ^a	17.92 ^a
100% v/v rabbit urine	4.50 ^a	7.75 ^a	10.92 ^a	11.54 ^c	13.00 ^b	11.71 ^a	10.17 ^b	7.25 ^b	5.34 ^b
0.1% v/v Duduthrin 1.75EC	4.21 ^a	8.75 ^a	14.42 ^a	17.88 ^{ab}	19.63 ^a	20.29 ^a	19.42 ^a	18.75 ^a	16.71 ^a

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

Table 12: Effect of rabbit urine foliar spray on the number of fruits per plant (no/plant) in trials 1 and 2.

Treatment	DAT							
	56	63	70	77	84	91	98	105
Trial 1								
0% v/v rabbit urine	1.00 ^b	2.96 ^b	6.30 ^b	11.46 ^b	16.04 ^a	19.79 ^a	25.79 ^{ab}	29.58 ^{ab}
18.2% v/v rabbit urine	1.25 ^b	3.17 ^b	6.21 ^b	11.63 ^b	18.67 ^a	23.17 ^a	28.54 ^{ab}	34.08 ^a
25% v/v rabbit urine	1.33 ^b	3.34 ^b	6.29 ^b	12.38 ^b	19.29 ^a	23.67 ^a	31.29 ^a	35.63 ^a
40% v/v rabbit urine	1.63 ^b	3.79 ^b	6.96 ^b	12.67 ^b	19.33 ^a	24.04 ^a	30.62 ^a	34.54 ^a
100% v/v rabbit urine	3.00 ^a	7.00 ^a	11.54 ^a	17.41 ^a	20.92 ^a	22.09 ^a	22.75 ^b	23.67 ^b
0.1% v/v Duduthrin 1.75EC	1.42 ^b	3.46 ^b	7.54 ^b	12.67 ^b	17.88 ^a	21.08 ^a	27.25 ^{ab}	31.21 ^a
Trial 2								
0% v/v rabbit urine	1.25 ^b	3.54 ^b	7.09 ^a	11.04 ^{ab}	16.59 ^b	19.71 ^b	23.21 ^b	26.79 ^b
18.2% v/v rabbit urine	1.33 ^b	3.75 ^{ab}	7.17 ^a	12.54 ^{ab}	19.38 ^{ab}	24.29 ^{ab}	28.96 ^a	33.46 ^a
25% v/v rabbit urine	1.54 ^b	3.88 ^{ab}	8.04 ^a	12.59 ^{ab}	20.92 ^a	25.48 ^a	29.79 ^a	33.96 ^a
40% v/v rabbit urine	1.62 ^b	4.17 ^{ab}	9.13 ^a	14.75 ^a	18.92 ^{ab}	24.13 ^{ab}	27.71 ^{ab}	31.25 ^{ab}
100% v/v rabbit urine	3.13 ^a	5.50 ^a	8.38 ^a	10.54 ^b	12.25 ^c	13.88 ^c	14.67 ^c	15.04 ^c
0.1% v/v Duduthrin 1.75EC	1.46 ^b	4.34 ^{ab}	8.58 ^a	12.13 ^{ab}	18.79 ^{ab}	21.79 ^{ab}	26.54 ^{ab}	30.80 ^{ab}

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

small fruits harvested per plant at 119 DAT of both trials (3.75 and 16.0 small fruits per plant in trials 1 and 2, respectively). In most sampling days of the first trial, there were no significant ($P \leq 0.05$) differences between treatment 0% v/v rabbit urine and all other treatments in terms of the number of small fruits harvested per plant. However in the second trial, there were significant ($P \leq 0.05$) differences between the number of small fruits per plant in treatment 0% v/v rabbit urine and those of all other treatments in most sampling days. In all sampling days of trial 1 and most sampling days of trial 2, there were no significant ($P \leq 0.05$) differences between treatment 0.1% v/v Duduthrin 1.75EC and treatments 18.2% v/v rabbit urine, 25% v/v rabbit urine, 40% v/v rabbit urine and 100% v/v rabbit urine.

(b) Number of Medium-sized Fruits (diameter: 4 – 6 cm)

The number of medium-sized fruits harvested per plant was also influenced by rabbit urine foliar spray in different sampling days (Table 14). In most sampling days of trial 1, the number of medium-sized fruits harvested per plant decreased with decrease in the concentration of rabbit urine foliar spray from 100% v/v to 25% v/v. Decreasing the rabbit urine spray concentration further from 25% v/v to 18.2% v/v increased the number of medium-sized fruits per plant in most sampling days of the same trial. However in the second trial, there was no permanent direction of influence of rabbit urine concentration on the number of medium-sized fruits harvested per plant. In most sampling days of the first trial, treatment 18.2% v/v rabbit urine registered the highest number of medium-sized fruits harvested per plant. In trial 1, the highest number of medium-sized fruits registered in treatment 18.2% v/v rabbit urine was 25.75 at 119 DAT. In most sampling days of the second trial, treatment 25% v/v rabbit urine registered the highest number of medium-sized fruits harvested per plant. In trial 2, the highest number of medium-sized fruits registered in treatment 25% v/v rabbit urine was 38.50 at 119 DAT. Treatment 100% v/v rabbit urine registered significantly ($P \leq 0.05$) higher number of medium-sized fruits than all other treatments at 77 DAT of both trials (3.50 and 4.25 medium-sized fruits per plant in trials 1 and 2, respectively). However, the numbers of medium-sized fruits in treatment 100% v/v rabbit urine reached their maximums, at 91 DAT of both trials (16.50 and 12.75 medium-sized fruits per plant in trials 1 and 2, respectively), after which the numbers started to decline. In most sampling days of both trials, the number of

medium-sized fruits harvested per plant in treatment 0.1% v/v Duduthrin 1.75EC was not significantly ($P \leq 0.05$) different from those in all other treatments.

(c) Number of Large Fruits (diameter: >6 cm)

Rabbit urine foliar spray had a significant concentration-dependent effect on the number of large fruits harvested per plant (table 15). In most sampling days of both trials, the number of large fruits harvested per plant increased with decrease in the concentration of rabbit urine foliar spray from 100% v/v to 18.2% v/v. Decreasing the concentration of rabbit urine foliar spray from 18.2% v/v to 0% v/v decreased the number of large fruits harvested per plant. At 91 DAT of the first trial, treatment 18.2% v/v recorded 39.00 large fruits as the highest number among all treatments in the entire trial. In trial 2, the highest number of large fruits harvested from all treatments was recorded in treatment 25% v/v rabbit urine and was 35.75. In trial 1, the number of large fruits harvested per plant in all treatments increased over time from 77 DAT to reach their maximum at 91 DAT, after which they started to decline until 119 DAT. In trial 2, the number of large fruits harvested per plant in all treatments except treatment 0% v/v rabbit urine (negative control) increased over time from 77 DAT to reach their maximum at 98 DAT, after which they started to decline until 119 DAT. In most sampling days of both trials, the number of large fruits harvested per plant in treatment 0.1% v/v Duduthrin 1.75EC was not significantly ($P \leq 0.05$) different from those in treatments 0% v/v rabbit urine, 18.2% v/v rabbit urine, 25% v/v rabbit urine and 40% v/v rabbit urine. Treatment 100% v/v rabbit urine registered higher numbers of large fruits than all other treatments at 77 DAT of both trials (12.25 and 11.25 large fruits per plant in trials 1 and 2, respectively). However, the numbers of large fruits in treatment 100% v/v rabbit urine reached their maximums at 91 DAT of trial 1 (28.50 large fruits per plant) and 77 DAT of trial 2 (11.25 large fruits per plant), after which the numbers started to decline up to 119 DAT of both trials.

4.3.4 Marketable Yield

(a) Number of Marketable Fruits per Plant

The number of marketable fruits per plant was also influenced significantly by the rabbit urine foliar spray in different sampling days (Table 16). At 77 DAT of both trials, treatment 100% v/v rabbit urine recorded significantly ($P \leq 0.05$) higher numbers of

Table 13: Effect of rabbit urine foliar spray on the number of small-sized fruits per plant (no/plant) in trials 1 and 2.

Treatment	DAT						
	77	84	91	98	105	112	119
Trial 1							
0% v/v rabbit urine	0.75 ^a	1.50 ^a	3.00 ^a	2.25 ^a	2.50 ^a	2.50 ^a	3.75 ^a
18.2% v/v rabbit urine	0.00 ^a	0.00 ^c	0.50 ^a	0.25 ^a	0.50 ^a	1.75 ^a	1.25 ^a
25% v/v rabbit urine	0.00 ^a	0.25 ^{bc}	0.50 ^a	0.50 ^a	1.00 ^a	1.75 ^a	2.00 ^a
40% v/v rabbit urine	0.00 ^a	0.50 ^{abc}	0.50 ^a	1.25 ^a	1.50 ^a	2.70 ^a	4.50 ^a
100% v/v rabbit urine	0.00 ^a	1.25 ^{ab}	2.00 ^a	5.25 ^a	3.00 ^a	2.75 ^a	1.50 ^a
0.1% v/v Duduthrin 1.75EC	0.25 ^a	0.00 ^c	0.00 ^a	0.25 ^a	0.00 ^a	1.25 ^a	1.00 ^a
Trial 2							
0% v/v rabbit urine	0.00 ^a	1.00 ^a	3.25 ^a	7.00 ^a	6.00 ^a	11.00 ^a	16.00 ^a
18.2% v/v rabbit urine	0.00 ^a	0.00 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.25 ^c	5.00 ^b
25% v/v rabbit urine	0.00 ^a	0.00 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.25 ^c	4.00 ^b
40% v/v rabbit urine	0.00 ^a	0.25 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.50 ^c	5.50 ^b
100% v/v rabbit urine	0.00 ^a	0.50 ^a	0.50 ^b	0.75 ^b	1.75 ^b	3.25 ^b	0.00 ^c
0.1% v/v Duduthrin 1.75EC	0.25 ^a	0.00 ^a	0.00 ^b	0.00 ^b	0.25 ^b	4.50 ^b	4.25 ^b

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

Table 14: Effect of rabbit urine foliar spray on the number of medium-sized fruits per plant (no/plant) in trials 1 and 2.

Treatment	DAT						
	77	84	91	98	105	112	119
Trial 1							
0% v/v rabbit urine	1.50 ^b	3.00 ^a	9.25 ^{ab}	5.50 ^a	4.75 ^a	13.75 ^a	13.75 ^{ab}
18.2% v/v rabbit urine	0.75 ^b	2.25 ^a	13.25 ^{ab}	13.25 ^a	10.00 ^a	14.25 ^a	25.75 ^a
25% v/v rabbit urine	0.50 ^b	1.75 ^a	10.25 ^{ab}	9.50 ^a	7.50 ^a	8.75 ^a	13.00 ^{ab}
40% v/v rabbit urine	1.00 ^b	1.75 ^a	12.50 ^{ab}	13.00 ^a	8.75 ^a	12.25 ^a	12.50 ^{ab}
100% v/v rabbit urine	3.50 ^a	3.25 ^a	16.50 ^a	10.75 ^a	9.25 ^a	14.00 ^a	6.25 ^b
0.1% v/v Duduthrin 1.75EC	0.50 ^b	1.00 ^a	5.50 ^b	7.50 ^a	3.50 ^a	11.75 ^a	16.50 ^{ab}
Trial 2							
0% v/v rabbit urine	0.75 ^b	1.75 ^a	14.25 ^a	12.85 ^{ab}	14.75 ^a	14.00 ^c	14.75 ^b
18.2% v/v rabbit urine	0.75 ^b	2.25 ^a	0.75 ^c	2.50 ^b	6.75 ^a	18.00 ^{ab}	31.00 ^a
25% v/v rabbit urine	0.25 ^b	2.00 ^a	14.30 ^a	18.50 ^a	14.90 ^a	28.50 ^a	38.50 ^a
40% v/v rabbit urine	1.50 ^b	1.75 ^a	4.00 ^{abc}	10.25 ^{ab}	8.00 ^a	18.00 ^{ab}	25.75 ^{ab}
100% v/v rabbit urine	4.25 ^a	6.75 ^a	12.75 ^{ab}	12.00 ^{ab}	5.75 ^a	3.50 ^{bc}	0.00 ^c
0.1% v/v Duduthrin 1.75EC	0.75 ^b	0.75 ^a	7.50 ^{abc}	8.25 ^{ab}	14.00 ^a	15.50 ^{ab}	37.00 ^a

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

Table 15: Effect of rabbit urine foliar spray on the number of large-sized fruits per plant (no/plant) in trials 1 and 2.

Treatment	DAT						
	77	84	91	98	105	112	119
Trial 1							
0% v/v rabbit urine	1.50 ^{ab}	11.00 ^b	22.25 ^b	15.75 ^{ab}	11.5 ^a	8.75 ^a	5.00 ^a
18.2% v/v rabbit urine	5.25 ^{ab}	25.50 ^a	39.00 ^a	22.00 ^a	15.50 ^a	6.75 ^{ab}	6.75 ^a
25% v/v rabbit urine	7.00 ^{ab}	22.00 ^{ab}	38.25 ^a	20.25 ^a	14.75 ^a	9.75 ^a	6.50 ^a
40% v/v rabbit urine	6.25 ^{ab}	20.25 ^{ab}	34.25 ^{ab}	20.00 ^{ab}	10.00 ^a	9.25 ^a	5.75 ^a
100% v/v rabbit urine	12.25 ^a	18.25 ^{ab}	28.50 ^{ab}	6.25 ^b	6.25 ^a	1.75 ^b	0.75 ^b
0.1% v/v Duduthrin 1.75EC	5.75 ^b	20.00 ^{ab}	34.00 ^{ab}	17.00 ^{ab}	15.25 ^a	7.75 ^a	7.75 ^a
Trial 2							
0% v/v rabbit urine	0.00 ^b	13.25 ^a	3.00 ^b	5.50 ^b	6.00 ^{bc}	2.50 ^{bc}	5.50 ^b
18.2% v/v rabbit urine	2.50 ^b	13.75 ^a	21.25 ^a	29.25 ^a	27.25 ^a	19.00 ^a	12.00 ^{ab}
25% v/v rabbit urine	4.00 ^b	16.00 ^a	27.75 ^a	35.75 ^a	32.50 ^a	21.25 ^a	15.00 ^a
40% v/v rabbit urine	2.75 ^b	14.50 ^a	20.00 ^a	26.00 ^a	24.75 ^{ab}	13.00 ^a	5.25 ^{ab}
100% v/v rabbit urine	11.25 ^a	9.25 ^a	6.50 ^b	4.75 ^b	1.50 ^c	0.00 ^c	0.00 ^c
0.1% v/v Duduthrin 1.75EC	3.50 ^b	10.00 ^a	12.25 ^{ab}	23.00 ^a	21.50 ^{ab}	8.25 ^{ab}	8.00 ^{ab}

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

marketable fruits than treatment 0% v/v rabbit urine (2.63 and 2.59 marketable fruits per plant in trials 1 and 2, respectively). In trial 1, the number of marketable fruits per plant increased with increase in the concentration of rabbit urine spray from 0% v/v to 18.2% v/v most sampling days. Increasing the concentration of rabbit urine spray further from 18.2% v/v to 100% v/v decreased the number of marketable fruits per plant. In most sampling days of the first trial, treatment 18.2% v/v rabbit urine registered the highest numbers of marketable fruits per plant, although they were not significantly ($P \leq 0.05$) different from those in treatment 0.1% v/v Duduthrin 1.75EC. At 91 DAT of trial 1, treatment 18.2% v/v rabbit urine registered the highest number of marketable fruits than all other treatments (8.67 marketable fruits per plant). In most sampling days of trial 2, the number of marketable fruits per plant increased with increase in the concentration of rabbit urine spray from 0% v/v to 25% v/v. Increasing the concentration of rabbit urine spray further from 25% v/v to 100% v/v decreased the number of marketable fruits per plant. In most sampling days of the second trial, treatment 25% v/v rabbit urine registered the highest numbers of marketable fruits per plant, although they were not significantly ($P \leq 0.05$) different from those in treatment 0.1% v/v Duduthrin 1.75EC. The highest number of marketable fruits in the second trial was recorded at 199 DAT by treatment 25% v/v rabbit urine (7.71 marketable fruits per plant).

(b) Weight of Marketable Fruits per Plant

Rabbit urine foliar spray had a significant concentration-dependent effect on the weight of marketable fruits per plant (table 17). At 77 DAT of both trials, treatment 100% v/v rabbit urine recorded significantly ($P \leq 0.05$) higher marketable fruit weights per plant than treatment 0% v/v rabbit urine (0.246 kg and 0.434 kg in trials 1 and 2, respectively). In trial 1, the marketable fruit weight per plant increased with increase in the concentration of rabbit urine spray from 0% v/v to 18.2% v/v most sampling days. Increasing the concentration of rabbit urine spray further from 18.2% v/v to 100% v/v decreased the marketable fruit weight per plant. In most sampling days of the first trial, treatment 18.2% v/v rabbit urine registered the highest marketable fruit weights per plant, although they were not significantly ($P \leq 0.05$) different from those in treatment 0.1% v/v Duduthrin 1.75EC. At 91 DAT of trial 1, treatment 18.2% v/v rabbit urine registered 0.798 kg as the highest marketable fruit weight per plant than all other treatments. In most

Table 16: Effect of rabbit urine foliar spray on the number of marketable fruits per plant (no/plant) in trials 1 and 2.

Treatment	DAT						
	77	84	91	98	105	112	119
Trial 1							
0% v/v rabbit urine	0.29 ^c	2.04 ^b	6.54 ^a	4.54 ^a	2.46 ^a	3.03 ^a	3.04 ^{ab}
18.2% v/v rabbit urine	1.04 ^{abc}	4.53 ^a	8.67 ^a	5.71 ^a	4.00 ^a	3.58 ^a	4.67 ^a
25% v/v rabbit urine	1.25 ^{bc}	3.92 ^{ab}	8.25 ^a	4.71 ^a	3.96 ^a	3.28 ^a	3.29 ^a
40% v/v rabbit urine	1.63 ^{ab}	3.59 ^{ab}	7.58 ^a	4.67 ^a	3.08 ^a	3.04 ^a	3.29 ^a
100% v/v rabbit urine	2.63 ^a	3.54 ^{ab}	6.42 ^a	2.79 ^a	2.54 ^a	2.67 ^a	1.17 ^b
0.1% v/v Duduthrin 1.75EC	1.25 ^{abc}	3.42 ^{ab}	6.46 ^a	4.09 ^a	3.13 ^a	3.25 ^a	3.71 ^a
Trial 2							
0% v/v rabbit urine	0.00 ^b	1.71 ^a	2.42 ^a	3.21 ^{bc}	3.04 ^{bc}	2.58 ^b	3.83 ^b
18.2% v/v rabbit urine	0.73 ^b	3.31 ^a	3.75 ^a	6.12 ^a	6.04 ^a	5.67 ^{ab}	7.67 ^a
25% v/v rabbit urine	0.88 ^{ab}	3.46 ^a	4.42 ^a	6.21 ^a	6.29 ^a	6.21 ^a	7.71 ^a
40% v/v rabbit urine	1.21 ^{ab}	2.75 ^a	3.42 ^a	4.50 ^{ab}	5.33 ^{ab}	4.92 ^{ab}	5.17 ^{ab}
100% v/v rabbit urine	2.59 ^a	2.42 ^a	3.08 ^a	2.38 ^c	1.75 ^c	0.58 ^c	0.00 ^c
0.1% v/v Duduthrin 1.75EC	0.75 ^b	1.71 ^a	3.13 ^a	4.25 ^{ab}	5.63 ^{ab}	5.33 ^{ab}	6.38 ^{ab}

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

Table 17: Effect of rabbit urine foliar spray on the weight of marketable fruits per plant (kg/plant) in trials 1 and 2.

Treatment	DAT						
	77	84	91	98	105	112	119
Trial 1							
0% v/v rabbit urine	0.047 ^b	0.242 ^a	0.546 ^{ab}	0.216 ^{ab}	0.192 ^{ab}	0.187 ^{ab}	0.137 ^{ab}
18.2% v/v rabbit urine	0.116 ^{ab}	0.501 ^a	0.798 ^a	0.473 ^a	0.327 ^a	0.240 ^a	0.242 ^a
25% v/v rabbit urine	0.146 ^{ab}	0.450 ^a	0.792 ^a	0.392 ^{ab}	0.326 ^a	0.232 ^{ab}	0.182 ^a
40% v/v rabbit urine	0.172 ^{ab}	0.417 ^a	0.684 ^{ab}	0.326 ^{ab}	0.229 ^{ab}	0.189 ^{ab}	0.140 ^{ab}
100% v/v rabbit urine	0.246 ^a	0.356 ^a	0.495 ^b	0.155 ^b	0.159 ^b	0.130 ^b	0.054 ^b
0.1% v/v Duduthrin 1.75EC	0.211 ^{ab}	0.398 ^a	0.670 ^{ab}	0.349 ^{ab}	0.327 ^a	0.219 ^{ab}	0.185 ^a
Trial 2							
0% v/v rabbit urine	0.000 ^b	0.171 ^a	0.217 ^b	0.278 ^{bc}	0.277 ^{bc}	0.219 ^c	0.139 ^c
18.2% v/v rabbit urine	0.076 ^{ab}	0.268 ^a	0.374 ^{ab}	0.597 ^a	0.608 ^a	0.466 ^{ab}	0.386 ^{ab}
25% v/v rabbit urine	0.104 ^{ab}	0.291 ^a	0.437 ^a	0.649 ^a	0.617 ^a	0.544 ^a	0.481 ^a
40% v/v rabbit urine	0.193 ^a	0.243 ^a	0.359 ^{ab}	0.494 ^a	0.500 ^a	0.326 ^b	0.254 ^{bc}
100% v/v rabbit urine	0.434 ^a	0.210 ^a	0.202 ^b	0.144 ^c	0.085 ^c	0.027 ^d	0.000 ^d
0.1% v/v Duduthrin 1.75EC	0.073 ^{ab}	0.188 ^a	0.283 ^{ab}	0.455 ^{ab}	0.461 ^{ab}	0.380 ^{ab}	0.306 ^{ab}

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

sampling days of trial 2, the marketable fruit weight per plant increased with increase in the concentration of rabbit urine spray from 0% v/v to 25% v/v. Increasing the concentration of rabbit urine spray further from 25% v/v to 100% v/v decreased the marketable fruit weight per plant. In most sampling days of the second trial, treatment 25% v/v rabbit urine registered the highest marketable fruit weights per plant, although they were not significantly ($P \leq 0.05$) different from those in treatment 0.1% v/v Duduthrin 1.75EC. The highest marketable fruit weight in the second trial was the 0.649 kg recorded at 98 DAT by treatment 25% v/v rabbit urine.

4.3.5 Non-marketable Yield

(a) Number of Non-marketable Fruits per Plant

Rabbit urine foliar spray significantly affected the number of non-marketable fruits per plant (table 18). In all sampling days of both trials, treatment 0% v/v rabbit urine (negative control) registered the highest number of non-marketable fruits. The highest numbers of non-marketable fruits per plant registered by treatment 0% v/v rabbit urine were 1.08 at 199 DAT of the first trial and 3.13 at 199 DAT of the second trial. Treatment 25% v/v rabbit urine gave the least numbers of non-marketable fruits in all sampling days of the first trial. Treatment 100% v/v rabbit urine recorded the least numbers of non-marketable fruits in most sampling days of the second trial. In most sampling days of both trials, the numbers of non-marketable fruits in treatment 0.1% v/v Duduthrin 1.75EC were not significantly ($P \leq 0.05$) different from those in treatments 25% v/v rabbit urine and 100% v/v rabbit urine. In most sampling days of the first trial, the number of non-marketable fruits decreased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 25% v/v. Increasing the concentration of rabbit urine spray from 25% v/v to 40% v/v increased the number of non-marketable fruits per plant. The number of non-marketable fruits started increasing again upon further increase in the concentration of rabbit urine from 40% v/v to 100% v/v. In all sampling days of the second trial, the number of non-marketable fruits decreased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 100% v/v.

Table 18: Effect of rabbit urine foliar spray on the number of non-marketable fruits per plant (no/plant) in trials 1 and 2.

Treatment	DAT						
	77	84	91	98	105	112	119
Trial 1							
0% v/v rabbit urine	0.54 ^a	0.29 ^a	0.46 ^a	0.96 ^a	0.50 ^a	0.54 ^a	1.08 ^a
18.2% v/v rabbit urine	0.00 ^b	0.21 ^a	0.17 ^a	0.17 ^a	0.21 ^a	0.38 ^a	0.42 ^a
25% v/v rabbit urine	0.00 ^b	0.11 ^a	0.13 ^a	0.08 ^a	0.04 ^a	0.21 ^a	0.21 ^a
40% v/v rabbit urine	0.00 ^b	0.29 ^a	0.38 ^a	0.46 ^a	0.50 ^a	0.50 ^a	0.75 ^a
100% v/v rabbit urine	0.00 ^b	0.26 ^a	0.25 ^a	0.34 ^a	0.38 ^a	0.46 ^a	0.25 ^a
0.1% v/v Duduthrin 1.75EC	0.08 ^b	0.17 ^a	0.21 ^a	0.09 ^a	0.09 ^a	0.34 ^a	0.50 ^a
Trial 2							
0% v/v rabbit urine	0.50 ^a	0.88 ^a	0.92 ^a	1.96 ^a	1.42 ^a	2.00 ^a	3.13 ^a
18.2% v/v rabbit urine	0.15 ^a	0.33 ^{ab}	0.17 ^{ab}	0.29 ^{ab}	0.29 ^b	0.54 ^{bc}	1.12 ^{ab}
25% v/v rabbit urine	0.00 ^a	0.00 ^c	0.09 ^b	0.21 ^b	0.25 ^b	0.38 ^c	0.92 ^{bc}
40% v/v rabbit urine	0.00 ^a	0.04 ^c	0.08 ^b	0.13 ^b	0.13 ^b	0.13 ^c	0.83 ^{bc}
100% v/v rabbit urine	0.00 ^a	0.09 ^{bc}	0.04 ^b	0.13 ^b	0.04 ^b	0.09 ^c	0.00 ^c
0.1% v/v Duduthrin 1.75EC	0.21 ^a	0.13 ^{bc}	0.25 ^{ab}	0.81 ^{ab}	0.50 ^{ab}	1.54 ^{ab}	2.08 ^{ab}

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

(b) Weight of Non-marketable Fruits per Plant

Rabbit urine foliar spray had a significant concentration-dependent effect on the weight of non-marketable fruits per plant (table 19). In all sampling days of both trials, treatment 0% v/v rabbit urine (negative control) registered the greatest weights of non-marketable fruits. The highest weights of non-marketable fruits per plant registered by treatment 0% v/v rabbit urine were 0.066 kg at 199 DAT of the first trial and 0.141 kg at 199 DAT of the second trial. Treatment 25% v/v rabbit urine gave the lowest weights of non-marketable fruits in all sampling days of the first trial. Treatment 100% v/v rabbit urine recorded the least weights of non-marketable fruits in most sampling days of the second trial. In most sampling days of both trials, the weights of non-marketable fruits in treatment 0.1% v/v Duduthrin 1.75EC were not significantly ($P \leq 0.05$) different from those in treatments 25% v/v rabbit urine and 100% v/v rabbit urine. In most sampling days of both trials, the weight of non-marketable fruits decreased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 25% v/v. Increasing the concentration of rabbit urine spray from 25% v/v to 40% v/v increased the weight of non-marketable fruits per plant. The weight of non-marketable fruits started increasing again upon further increase in the concentration of rabbit urine from 40% v/v to 100% v/v.

4.3.6 Total Yield

(a) Total Number of Fruits per Plant

The total number of fruits per plant was also influenced by rabbit urine foliar spray in different sampling weeks (Table 20). In most sampling days of trial 1, the total number of fruits per plant increased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 18.2% v/v and from 25% v/v to 40% v/v. Increase in the concentration of rabbit urine foliar spray from 18.2% v/v to 25% v/v and from 40% v/v to 100% v/v led to decline in the total number of fruits per plant. In the same trial, treatment 18.2% v/v rabbit urine recorded the highest total numbers of fruits per plant in most sampling days, with 8.83 fruits per plant at 91 DAT being its highest value. Mostly in trial 2, the total number of fruits per plant increased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 25% v/v. Further increase in the concentration of rabbit urine foliar spray from 25% v/v to 100% v/v led to decline in the total number of

Table 19: Effect of rabbit urine foliar spray on the weight of non-marketable fruits per plant (kg/plant) in trials 1 and 2.

Treatment	DAT						
	77	84	91	98	105	112	119
Trial 1							
0% v/v rabbit urine	0.016 ^a	0.053 ^a	0.021 ^a	0.030 ^a	0.029 ^a	0.064 ^a	0.066 ^a
18.2% v/v rabbit urine	0.000 ^b	0.016 ^a	0.011 ^a	0.013 ^a	0.006 ^{ab}	0.009 ^a	0.010 ^a
25% v/v rabbit urine	0.000 ^b	0.016 ^a	0.007 ^a	0.002 ^a	0.002 ^b	0.006 ^a	0.003 ^a
40% v/v rabbit urine	0.000 ^b	0.019 ^a	0.014 ^a	0.017 ^a	0.012 ^{ab}	0.029 ^a	0.031 ^a
100% v/v rabbit urine	0.000 ^b	0.016 ^a	0.010 ^a	0.005 ^a	0.006 ^{ab}	0.007 ^a	0.003 ^a
0.1% v/v Duduthrin 1.75EC	0.004 ^b	0.029 ^a	0.015 ^a	0.019 ^a	0.013 ^{ab}	0.026 ^a	0.032 ^a
Trial 2							
0% v/v rabbit urine	0.035 ^a	0.081 ^a	0.077 ^a	0.182 ^a	0.142 ^a	0.150 ^a	0.141 ^a
18.2% v/v rabbit urine	0.012 ^a	0.005 ^c	0.008 ^b	0.031 ^a	0.020 ^b	0.020 ^b	0.017 ^b
25% v/v rabbit urine	0.000 ^a	0.001 ^c	0.002 ^b	0.021 ^a	0.007 ^b	0.006 ^b	0.012 ^b
40% v/v rabbit urine	0.000 ^a	0.013 ^{bc}	0.020 ^b	0.104 ^a	0.008 ^b	0.030 ^b	0.018 ^b
100% v/v rabbit urine	0.000 ^a	0.000 ^c	0.002 ^b	0.009 ^a	0.003 ^b	0.005 ^b	0.000 ^b
0.1% v/v Duduthrin 1.75EC	0.008 ^a	0.032 ^b	0.021 ^b	0.167 ^a	0.060 ^b	0.139 ^a	0.089 ^{ab}

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

Table 20: Effect of rabbit urine foliar spray on the total number of fruits per plant (no/plant) in trials 1 and 2.

Treatment	DAT						
	77	84	91	98	105	112	119
Trial 1							
0% v/v rabbit urine	0.84 ^b	3.71 ^a	7.00 ^a	5.00 ^a	3.17 ^a	3.46 ^a	5.75 ^a
18.2% v/v rabbit urine	1.04 ^b	4.69 ^a	8.83 ^a	5.88 ^a	4.38 ^a	4.04 ^a	3.71 ^{ab}
25% v/v rabbit urine	1.25 ^b	3.79 ^a	7.75 ^a	5.04 ^a	3.59 ^a	3.63 ^a	3.50 ^{ab}
40% v/v rabbit urine	1.63 ^{ab}	4.21 ^a	8.50 ^a	5.05 ^a	4.04 ^a	3.83 ^a	3.79 ^{ab}
100% v/v rabbit urine	2.63 ^a	2.34 ^a	6.58 ^a	4.29 ^a	2.75 ^a	3.04 ^a	1.42 ^b
0.1% v/v Duduthrin 1.75EC	1.33 ^b	3.68 ^a	6.79 ^a	4.75 ^a	2.96 ^a	3.37 ^a	4.21 ^{ab}
Trial 2							
0% v/v rabbit urine	0.50 ^b	2.34 ^a	3.29 ^a	4.79 ^a	4.46 ^{ab}	4.59 ^c	5.71 ^b
18.2% v/v rabbit urine	0.88 ^b	3.25 ^a	3.83 ^a	6.25 ^a	6.17 ^a	6.59 ^{ab}	8.50 ^{ab}
25% v/v rabbit urine	0.94 ^b	3.50 ^a	4.46 ^a	6.42 ^a	6.54 ^a	6.88 ^a	8.83 ^a
40% v/v rabbit urine	1.21 ^b	2.50 ^a	3.42 ^a	5.17 ^a	5.46 ^a	4.75 ^{bc}	6.09 ^{ab}
100% v/v rabbit urine	2.59 ^a	1.84 ^a	3.17 ^a	2.50 ^a	2.04 ^b	1.54 ^d	0.00 ^c
0.1% v/v Duduthrin 1.75EC	0.83 ^b	2.67 ^a	3.67 ^a	5.21 ^a	6.13 ^a	5.79 ^{abc}	8.46 ^{ab}

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

fruits per plant. In the same trial, treatment 25% v/v rabbit urine recorded the highest total numbers of fruits per plant in most sampling days, with 8.83 fruits per plant at 119 DAT being its highest value. However, in all sampling days of both trials, the total numbers of fruits per plant in treatment 0.1% v/v Duduthrin 1.75EC were not significantly ($P \leq 0.05$) different from those in treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine. In most sampling days of both trials, treatment 100% v/v rabbit urine recorded the least total numbers of fruits per plant. At 77 DAT of both trials, treatment 100% v/v rabbit urine gave the highest total numbers of fruits (2.63 and 2.59 fruits per plant in trials 1 and 2, respectively). However, at 119 DAT, treatment 100% v/v rabbit urine gave the lowest total numbers of fruits (1.42 and 0.00 fruits per plant in trials 1 and 2, respectively).

(b) Total Weight of Fruits per Plant

Rabbit urine foliar spray significantly affected the total weight of fruits per plant (Table 21). In most sampling days of trial 1, the total weight of fruits per plant increased with increase in the concentration of rabbit urine spray from 0% v/v to 18.2% v/v. Further increase in the concentration of rabbit urine spray from 18.2% v/v to 100% v/v led to a decrease in the total weight of fruits per plant. In the same trial, treatment 18.2% v/v rabbit urine registered the highest total weights of fruits in most sampling days, with 0.807 kg/plant at 91 DAT being its highest value. In most sampling days of trial 2, the total weight of fruits per plant increased with increase in the concentration of rabbit urine spray from 0% v/v to 25% v/v. Further increase in the concentration of rabbit urine spray from 25% v/v to 100% v/v led to a decrease in the total weight of fruits per plant. In the same trial, treatment 25% v/v rabbit urine registered the highest total weights of fruits in most sampling days, with 0.636 kg/plant at 105 DAT being its highest value. In all sampling days of both trials, the total weights of fruits per plant in treatment 0.1% v/v Duduthrin 1.75EC were not significantly ($P \leq 0.05$) different from those in treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine. In most sampling days of both trials, treatment 100% v/v rabbit urine recorded the least total weights of fruits per plant. At 77 DAT of both trials, treatment 100% v/v rabbit urine gave the highest total weights of fruits (0.246 kg/plant and 0.193 kg/plant in trials 1 and 2, respectively). However, at 119 DAT, treatment 100% v/v rabbit urine gave the lowest total weights of fruits (0.057 kg/plant and 0.00 kg/plant in trials 1 and 2, respectively).

Table 21: Effect of rabbit urine foliar spray on the total weight of fruits per plant (kg/plant) in trials 1 and 2.

Treatment	DAT						
	77	84	91	98	105	112	119
Trial 1							
0% v/v rabbit urine	0.109 ^a	0.295 ^a	0.667 ^{ab}	0.397 ^a	0.204 ^a	0.202 ^{ab}	0.284 ^a
18.2% v/v rabbit urine	0.116 ^a	0.466 ^a	0.807 ^a	0.486 ^a	0.339 ^a	0.282 ^a	0.193 ^a
25% v/v rabbit urine	0.146 ^a	0.426 ^a	0.694 ^{ab}	0.394 ^a	0.328 ^a	0.240 ^{ab}	0.189 ^a
40% v/v rabbit urine	0.172 ^a	0.372 ^a	0.683 ^{ab}	0.366 ^a	0.291 ^a	0.225 ^{ab}	0.203 ^a
100% v/v rabbit urine	0.246 ^a	0.157 ^a	0.505 ^b	0.174 ^a	0.165 ^a	0.138 ^b	0.057 ^b
0.1% v/v Duduthrin 1.75EC	0.215 ^a	0.436 ^a	0.805 ^a	0.397 ^a	0.329 ^a	0.248 ^{ab}	0.272 ^a
Trial 2							
0% v/v rabbit urine	0.023 ^b	0.214 ^a	0.293 ^{ab}	0.445 ^b	0.419 ^b	0.358 ^b	0.227 ^{bc}
18.2% v/v rabbit urine	0.084 ^{ab}	0.274 ^a	0.390 ^{ab}	0.618 ^{ab}	0.616 ^{ab}	0.476 ^{ab}	0.454 ^{ab}
25% v/v rabbit urine	0.092 ^{ab}	0.291 ^a	0.439 ^a	0.670 ^a	0.636 ^a	0.574 ^a	0.498 ^a
40% v/v rabbit urine	0.104 ^{ab}	0.268 ^a	0.382 ^{ab}	0.559 ^{ab}	0.521 ^{ab}	0.471 ^{ab}	0.415 ^{ab}
100% v/v rabbit urine	0.193 ^a	0.183 ^a	0.203 ^b	0.153 ^c	0.092 ^c	0.048 ^c	0.000 ^c
0.1% v/v Duduthrin 1.75EC	0.087 ^{ab}	0.268 ^a	0.307 ^{ab}	0.525 ^{ab}	0.503 ^{ab}	0.388 ^{ab}	0.266 ^{ab}

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

4.3.7 Total Marketable Yield

Rabbit urine foliar spray had a significant concentration-dependent effect on the total marketable yield per hectare (table 22). In trial 1, the total marketable yield per hectare increased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 18.2% v/v. Increasing the concentration of rabbit urine spray further from 18.2% v/v to 100% v/v led to a decrease in the total marketable yield per hectare. Treatment 18.2% v/v registered the highest total marketable yield (1499167 fruits per ha and 129.14 t ha⁻¹). In trial 2, the total marketable yield per hectare increased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 25% v/v. Increasing the concentration of rabbit urine spray further from 25% v/v to 100% v/v led to a decrease in the total marketable yield per hectare. Treatment 25% v/v registered the highest total marketable yield (1710852 fruits per ha and 165.08 t ha⁻¹). However, in both trials, the total marketable yields of in treatment 0.1% v/v Duduthrin 1.75EC were not significantly ($P \leq 0.05$) different from those in treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine. Treatment 100% v/v rabbit urine recorded the lowest total marketable fruits per hectare (1130111 fruits per ha and 700000 fruits per ha in trials 1 and 2, respectively) and total weight of marketable fruits per hectare (82.63 t ha⁻¹ and 44.59 t ha⁻¹ in trials 1 and 2, respectively) in both trials.

4.3.8 Total Non-marketable Yield

The total non-marketable yield was also influenced significantly by rabbit urine foliar spray (Table 23). In the first trial, the total number of non-marketable yield per hectare decreased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 25% v/v and from 40% v/v to 100% v/v. Increase in rabbit urine spray concentration from 25% v/v to 40% v/v led to increase in the total number of non-marketable fruits per hectare. In the second trial, the total number of non-marketable yield per hectare decreased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 100% v/v. In both trials, treatment 0% v/v rabbit urine recorded the highest total numbers of non-marketable fruits (198852 fruits per ha and 559870 fruits per ha in trials 1 and 2, respectively). In both trials, the total weight of non-marketable fruits per hectare decreased with increase in the concentration of rabbit urine spray from 0% v/v to 25% v/v and from 40% v/v to 100% v/v. Increase in the concentration of rabbit

urine spray from 25% v/v to 40% v/v led to increase in the total weight of non-marketable fruits per hectare. Treatment 0% v/v rabbit urine recorded the highest total weights of non-marketable fruits in both trials, with 12.93 t ha⁻¹ in trial 1 and 37.79 t ha⁻¹ in trial 2. Treatment 25% v/v rabbit urine recorded the lowest total non-marketable yield (54056 fruits per ha and 2.02 t ha⁻¹) in the first trial while treatment 100% v/v rabbit urine

Table 22: Effects rabbit urine foliar spray 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
0% v/v rabbit urine	1270370 ^{bc}	8707222 ^b	107.58 ^a	68.28 ^{cd}
18.2% v/v rabbit urine	1499167 ^a	1619333 ^a	129.14 ^a	145.70 ^{ab}
25% v/v rabbit urine	1468315 ^{ab}	1710852 ^a	127.18 ^a	165.08 ^a
40% v/v rabbit urine	1451722 ^{ab}	1587963 ^a	120.73 ^a	132.83 ^{ab}
100% v/v rabbit urine	1130111 ^c	700000 ^b	82.63 ^b	44.59 ^d
0.1% v/v Duduthrin 1.75EC	1311593 ^{ab}	1408556 ^a	125.09 ^a	107.72 ^{bc}

*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.

Table 23: Effects rabbit urine foliar spray 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
0% v/v rabbit urine	198852 ^a	559870 ^a	12.93 ^a	37.79 ^a
18.2% v/v rabbit urine	99296 ^{ab}	131444 ^{bc}	5.16 ^{ab}	8.35 ^{bc}
25% v/v rabbit urine	54056 ^b	86333 ^c	2.02 ^b	3.10 ^c
40% v/v rabbit urine	129759 ^{ab}	65074 ^c	6.55 ^{ab}	10.71 ^c
100% v/v rabbit urine	123148 ^{ab}	58463 ^c	3.21 ^b	2.23 ^c
0.1% v/v Duduthrin 1.75EC	67667 ^b	278535 ^b	7.65 ^{ab}	25.65 ^{ab}

*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.

recorded the least (58463 fruits per ha and 2.23 t ha⁻¹) in the second trial. In trial 1, the total non-marketable yield per hectare in treatment 0.1% v/v Duduthrin 1.75EC was not significantly ($P \leq 0.05$) different from that recorded in treatment 25% v/v rabbit urine. However, in trial 2, the total non-marketable yield per hectare in treatment 25% v/v rabbit urine was significantly ($P \leq 0.05$) lower than that in treatment 0.1% v/v Duduthrin 1.75EC.

4.3.9 Grand Total Yield

The grand total yield, in terms of number of fruits per hectare (no/ha) and fruit weight per hectare (t/ha), was influenced by rabbit urine foliar spray (Table 24). In trial 1, the grand total number of fruits per hectare increased with increase in rabbit urine spray concentration from 0% v/v to 18.2% v/v and from 25% v/v to 40% v/v. The grand total number of fruits per hectare decreased with increase in rabbit urine spray concentration from 18.2% v/v to 25% v/v and from 40% v/v to 100% v/v. In the same trial, the grand total weight of fruits per hectare increased with increase in rabbit urine spray concentration from 0% v/v to 18.2% v/v. The grand total weight of fruits per hectare decreased with increase in rabbit urine spray concentration from 18.2% v/v to 100% v/v. Treatment 18.2% v/v rabbit urine recorded the highest grand total yield (1598981 fruits per ha and 133.61 t ha⁻¹) while treatment 100% v/v rabbit urine registered the lowest (1253259 fruits per ha and 85.88 t ha⁻¹) in the first trial. In trial 2, the grand total number

Table 24: Effects rabbit urine foliar spray 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
0% v/v rabbit urine	1469352 ^{ab}	1430593 ^a	120.50 ^a	106.06 ^b
18.2% v/v rabbit urine	1598981 ^a	1750778 ^a	133.61 ^a	154.05 ^a
25% v/v rabbit urine	1521981 ^{ab}	1797185 ^a	129.20 ^a	168.18 ^a
40% v/v rabbit urine	1581481 ^a	1653037 ^a	127.28 ^a	143.54 ^{ab}
100% v/v rabbit urine	1253259 ^b	758463 ^b	85.88 ^b	46.82 ^c
0.1% v/v Duduthrin 1.75EC	1385481 ^{ab}	1687091 ^a	129.81 ^a	133.38 ^{ab}

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

of fruits per hectare increased with increase in rabbit urine spray concentration from 0% v/v to 25% v/v. The grand total number of fruits per hectare decreased with further increase in rabbit urine spray concentration from 25% v/v to 100% v/v. In the same trial, the grand total weight of fruits per hectare increased with increase in rabbit urine spray concentration from 0% v/v to 25% v/v. Further increase in the concentration of rabbit urine foliar spray from 25% v/v to 100% v/v led to decline in the grand total weight of fruits per hectare. Treatment 25% v/v rabbit urine recorded the highest grand total yield (1797185 fruits per ha and 168.18 t ha⁻¹) while treatment 100% v/v rabbit urine registered the lowest (758463 fruits per ha and 46.82 t ha⁻¹) in the first trial. However, in both trials, the grand total yield in treatment 0.1% v/v Duduthrin 1.75EC was not significantly ($P \leq 0.05$) different from that recorded in treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine.

4.4 Effect of Different Concentrations of Rabbit Urine Foliar Spray on tomato fruit post-harvest quality

4.4.1 Fruit Firmness

Rabbit urine foliar spray significantly influenced fruit firmness during storage (table 25). As expected, fruit firmness decreased with ripening of tomato fruits in both trials. In both trials, fruit firmness decreased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 100% v/v. Treatment 100% v/v rabbit urine recorded the lowest fruit firmness in all sampling days of both trials. At 12 storage days (SD) of both trials, treatment 100% v/v rabbit urine registered 2.23 KgF in trial 1 and 2.35 KgF in trial 2 as the lowest fruit firmness values. The highest fruit firmness was recorded at 0 SD of both trials by treatment 0.1% v/v Duduthrin 1.75EC (3.80 KgF in trial 1 and 3.80 KgF in trial 2). In all sampling days of both trials, fruit firmness in treatment 0.1% v/v Duduthrin 1.75EC was significantly ($P \leq 0.05$) higher than that recorded in treatments 18.2% v/v rabbit urine, 25% v/v rabbit urine, 40% v/v rabbit urine and 100% v/v rabbit urine.

4.4.2 Total Soluble Solids (TSS)

Rabbit urine foliar spray had a significant concentration-dependent effect on the total soluble solids (TSS) contents of fruits during storage (table 26). Contrary to fruit

firmness, total soluble solids content of the tomato fruits from all treatments increased with ripening of the fruits. In both trials, TSS content increased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 100% v/v. Treatment 100% v/v rabbit urine recorded the highest TSS contents in all sampling days of both trials. The highest TSS contents registered in treatment 100% v/v rabbit urine were 3.45 °Brix at 12 storage days (SD) of trial 1 and 3.55 °Brix at 12 SD of trial 2. In most sampling days of trial 1 and in all sampling days of trial 2, fruit TSS content in treatment 0.1% v/v Duduthrin 1.75EC was significantly ($P \leq 0.05$) lower than that in treatment 100% v/v rabbit urine. However, in all sampling days of both trials, fruit TSS contents in treatment 0.1% v/v Duduthrin 1.75EC were not significantly ($P \leq 0.05$) different from those recorded in treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine.

Table 25: Effect rabbit urine foliar spray on fruit firmness (KgF) in trials 1 and 2.

Treatment	Storage days				
	0	3	6	9	12
Trial 1					
0% v/v rabbit urine	3.70 ^{ab}	3.50 ^a	3.18 ^a	2.88 ^b	2.73 ^b
18.2% v/v rabbit urine	3.55 ^{bc}	3.28 ^b	2.93 ^b	2.70 ^{bc}	2.53 ^c
25% v/v rabbit urine	3.55 ^{bc}	3.25 ^b	2.88 ^{bc}	2.60 ^{cd}	2.50 ^c
40% v/v rabbit urine	3.50 ^c	3.10 ^{bc}	2.73 ^{bc}	2.50 ^d	2.38 ^{cd}
100% v/v rabbit urine	3.20 ^d	2.95 ^c	2.68 ^c	2.43 ^d	2.23 ^d
0.1% v/v Duduthrin 1.75EC	3.80 ^a	3.65 ^a	3.38 ^a	3.08 ^a	2.93 ^a
Trial 2					
0% v/v rabbit urine	3.70 ^{ab}	3.53 ^{ab}	3.28 ^{ab}	2.93 ^{ab}	2.80 ^{ab}
18.2% v/v rabbit urine	3.58 ^{bc}	3.35 ^{bc}	3.03 ^{bc}	2.73 ^{bc}	2.58 ^{bc}
25% v/v rabbit urine	3.58 ^{bc}	3.33 ^{bc}	2.90 ^{cd}	2.70 ^{bc}	2.58 ^{bc}
40% v/v rabbit urine	3.48 ^c	3.15 ^{cd}	2.80 ^{cd}	2.58 ^{cd}	2.45 ^c
100% v/v rabbit urine	3.23 ^d	2.95 ^d	2.65 ^d	2.40 ^d	2.35 ^c
0.1% v/v Duduthrin 1.75EC	3.80 ^a	3.65 ^a	3.40 ^a	3.13 ^a	2.98 ^a

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

Table 26: Effect rabbit urine foliar spray on fruit total soluble solids ($^{\circ}$ Brix) in trials 1 and 2.

Treatment	Storage days				
	0	3	6	9	12
Trial 1					
0% v/v rabbit urine	2.60 ^c	2.70 ^c	2.85 ^b	2.95 ^b	3.00 ^d
18.2% v/v rabbit urine	2.80 ^{bc}	2.85 ^{bc}	2.95 ^b	3.05 ^{ab}	3.10 ^{cd}
25% v/v rabbit urine	2.85 ^b	2.85 ^{bc}	3.00 ^{ab}	3.10 ^{ab}	3.20 ^{bc}
40% v/v rabbit urine	2.95 ^{ab}	3.00 ^{ab}	3.05 ^{ab}	3.15 ^{ab}	3.30 ^{ab}
100% v/v rabbit urine	3.10 ^a	3.10 ^a	3.25 ^a	3.25 ^a	3.45 ^a
0.1% v/v Duduthrin 1.75EC	2.80 ^{bc}	2.85 ^{bc}	3.00 ^{ab}	3.10 ^{ab}	3.20 ^{bc}
Trial 2					
0% v/v rabbit urine	2.45 ^c	2.60 ^c	2.75 ^c	2.85 ^d	2.95 ^d
18.2% v/v rabbit urine	2.70 ^{bc}	2.80 ^{bc}	2.90 ^{bc}	2.95 ^{cd}	3.05 ^{cd}
25% v/v rabbit urine	2.80 ^{ab}	2.85 ^b	2.95 ^{abc}	3.05 ^{bc}	3.15 ^c
40% v/v rabbit urine	2.90 ^{ab}	2.95 ^b	3.10 ^{ab}	3.15 ^b	3.35 ^b
100% v/v rabbit urine	3.10 ^a	3.15 ^a	3.25 ^a	3.35 ^a	3.55 ^a
0.1% v/v Duduthrin 1.75EC	2.70 ^{bc}	2.80 ^{bc}	2.90 ^{bc}	3.00 ^{bcd}	3.10 ^{cd}

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

4.4.3 Titratable Acidity (TA)

The titratable acidity (TA) content of tomato fruits during storage was significantly influenced by rabbit urine foliar spray concentration (table 27). Titratable acidity content of the tomato fruits from all treatments decreased over the storage period from 0 storage days (SD) to 12 SD. In both trials, TA content increased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 100% v/v. Treatment 100% v/v rabbit urine recorded the highest TA contents in all sampling days of both trials. The highest TA contents registered in treatment 100% v/v rabbit urine were 81.58% ppm at 0 SD of trial 1 and 80.95% ppm at 0 SD of trial 2. In all sampling days of both trials, fruit TA content in treatment 0.1% v/v Duduthrin 1.75EC was significantly ($P \leq 0.05$) lower than that recorded in treatment 100% v/v rabbit urine. However, fruit TA contents in

treatment 0.1% v/v Duduthrin 1.75EC were not significantly ($P \leq 0.05$) different from those recorded in treatments 18.2% v/v rabbit urine, 25% v/v rabbit urine and 40% v/v rabbit urine in all sampling days of both trials.

Table 27: Effect rabbit urine foliar spray on fruit titratable acidity (% ppm) in trials 1 and 2.

Treatment	Storage days				
	0	3	6	9	12
Trial 1					
0% v/v rabbit urine	59.85 ^c	57.60 ^c	54.08 ^c	50.00 ^c	46.58 ^c
18.2% v/v rabbit urine	65.30 ^{bc}	62.40 ^{bc}	58.58 ^{bc}	55.05 ^{bc}	51.85 ^{bc}
25% v/v rabbit urine	67.55 ^{bc}	65.28 ^{bc}	62.73 ^b	59.20 ^b	56.00 ^b
40% v/v rabbit urine	69.43 ^b	68.15 ^b	65.28 ^b	60.80 ^b	58.55 ^b
100% v/v rabbit urine	81.58 ^a	79.38 ^a	75.50 ^a	71.68 ^a	67.20 ^a
0.1% v/v Duduthrin 1.75EC	68.50 ^b	66.88 ^b	63.35 ^b	58.88 ^b	56.00 ^b
Trial 2					
0% v/v rabbit urine	59.20 ^c	57.60 ^c	52.83 ^c	49.35 ^c	47.05 ^d
18.2% v/v rabbit urine	64.95 ^{bc}	61.43 ^{bc}	56.95 ^{bc}	53.20 ^{bc}	50.65 ^{cd}
25% v/v rabbit urine	68.18 ^b	65.93 ^b	61.75 ^b	58.22 ^b	55.67 ^{bc}
40% v/v rabbit urine	69.43 ^b	67.20 ^b	63.02 ^b	59.53 ^b	58.22 ^b
100% v/v rabbit urine	80.95 ^a	79.05 ^a	74.23 ^a	71.35 ^a	68.80 ^a
0.1% v/v Duduthrin 1.75EC	67.85 ^b	66.23 ^b	62.40 ^b	57.28 ^b	55.05 ^{bc}

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

4.4.4 Sugar Acid Ratio (TSS/TA)

Rabbit urine foliar spray had a significant concentration-dependent effect on the sugar acid ratio of fruits during storage (table 28). Fruit sugar acid ratio in all treatments increased over the storage period from 0 storage days (SD) to 12 SD. In both trials, fruit sugar acid ratio decreased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 100% v/v. Treatment 100% v/v rabbit urine recorded the lowest fruit sugar acid ratio in all sampling days of both trials. At 0 SD of both trials, treatment 100%

v/v rabbit urine registered 382.01 in trial 1 and 384.21 in trial 2 as the lowest fruit sugar acid ratios. The highest fruit sugar acid ratio was recorded at 12 SD of both trials by treatment 0% v/v rabbit urine (644.04 in trial 1 and 628.35 in trial 2). In all sampling days of both trials, fruit sugar acid ratios in treatment 0.1% v/v Duduthrin 1.75EC did not differ significantly ($P \leq 0.05$) from those recorded in treatments 18.2% v/v rabbit urine, 25% v/v rabbit urine, 40% v/v rabbit urine and 100% v/v rabbit urine.

Table 28: Effect rabbit urine foliar spray on sugar acid ratio (TSS:TA) in trials 1 and 2.

Treatment	Storage days				
	0	3	6	9	12
Trial 1					
0% v/v rabbit urine	434.66 ^a	469.25 ^a	527.72 ^a	592.34 ^a	644.04 ^a
18.2% v/v rabbit urine	428.81 ^{ab}	456.99 ^a	512.50 ^a	555.08 ^a	598.38 ^{ab}
25% v/v rabbit urine	424.85 ^{ab}	440.21 ^{ab}	470.04 ^{ab}	523.57 ^{ab}	570.86 ^{bc}
40% v/v rabbit urine	421.86 ^{ab}	436.59 ^{ab}	466.73 ^{ab}	518.06 ^{ab}	563.66 ^{bc}
100% v/v rabbit urine	382.01 ^b	392.35 ^b	433.01 ^b	455.75 ^b	516.29 ^c
0.1% v/v Duduthrin 1.75EC	409.73 ^{ab}	426.16 ^{ab}	473.44 ^{ab}	527.04 ^{ab}	571.80 ^{bc}
Trial 2					
0% v/v rabbit urine	419.55 ^a	451.51 ^a	520.74 ^a	578.42 ^a	628.35 ^a
18.2% v/v rabbit urine	418.06 ^a	456.91 ^a	510.54 ^a	557.14 ^a	605.46 ^a
25% v/v rabbit urine	417.09 ^a	432.26 ^{ab}	492.48 ^{ab}	529.52 ^{ab}	575.78 ^{ab}
40% v/v rabbit urine	414.11 ^a	439.86 ^{ab}	478.00 ^{ab}	523.79 ^{ab}	566.23 ^{ab}
100% v/v rabbit urine	384.21 ^a	399.75 ^b	440.12 ^b	471.88 ^b	518.24 ^b
0.1% v/v Duduthrin 1.75EC	397.74 ^a	422.78 ^{ab}	464.66 ^{ab}	523.58 ^{ab}	563.36 ^{ab}

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

CHAPTER FIVE

DISCUSSION

5.1 Effect of Different Concentrations of Rabbit Urine Foliar Spray on Whitefly Population

Adult whitefly population and incidence of adult whiteflies decreased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 100% v/v. This automatically led to increase in the efficacy of rabbit urine against adult whiteflies with increase in rabbit urine spray concentration. This could be due to the fact that the percentage of ammonia and ammonium bicarbonate increased as rabbit urine spray concentration increased. Previous studies by Durán-Lara *et al.* (2020) suggest that rabbit urine contains higher proportions of ammonia than urine from other mammalian animals since rabbits drink very little amounts of water. Since the ammonia in rabbit urine is highly volatile, it easily dissolves in water to form toxic ammonium bicarbonate (Leoni *et al.*, 2018). Lekamoi *et al.* (2022) further explained that the ammonium bicarbonate controls whiteflies through contact toxicity. They also added that once inhaled into the bodies of these pests, the corrosive ammonia destroys the respiratory surfaces of the whiteflies, hence killing them. Nonye (2021) also explained that the pungent smell from rabbit urine repels adult whiteflies. The higher the concentration of rabbit urine, the stronger the pungent smell of the ammonia in the urine (Dias *et al.*, 2019).

Moreover, scorching of plant foliage increased with increase in the concentration of rabbit urine foliar spray. The most scorched plants recorded the lowest populations and incidences of adult whiteflies, and hence higher efficacies of rabbit urine against adult whiteflies. FAO (2012) observed that spraying plants with concentrated rabbit urine scorches plant foliage. Salam *et al.* (2012) further explained that plants with high foliage intensities attract higher adult whitefly populations as compared to highly scorched plants.

The population of adult whiteflies increased over time in treatment 0% v/v rabbit urine (negative control), leading to higher incidences of the adults. This is because the negative control consisted of water sprays alone. Unlike rabbit urine, water sprays do not contain ammonia and ammonium bicarbonate, hence lowering the efficacy of the negative control against adult whiteflies. Therefore, the low efficacy led to build-up of

adult whitefly populations over time in the negative control. Although water sprays kill whiteflies by suffocating them, this method is not as effective as chemical, biological, cultural and integrated pest management methods of pest control (Zayed *et al.*, 2022). At first, adult whitefly populations in treatment 0.1% v/v Duduthrin 1.75EC (positive control) reduced over time to reach their minimums at 42 DAT of both trials, after when the populations started to increase drastically. This could be due to resistance development by the whiteflies against the synthetic chemical over time. Ghosal *et al.* (2018) explained that repeated spraying of whiteflies with synthetic pesticides like lambda cyhalothrin (the active ingredient of Duduthrin 1.75EC) leads to development of pest resistance, hence lowering the efficacy of the synthetic pesticide against adult whiteflies. Additionally, plant foliage in treatments 0% v/v rabbit urine (negative control) and 0.1% v/v Duduthrin 1.75EC (positive control) was not scorched, thus attracting more adult whiteflies.

The number of whitefly nymphs decreased with increase in the concentration of rabbit urine foliar spray. Additionally, the efficacy of rabbit urine against whitefly nymphs increased with increase in rabbit urine spray concentration. The ammonia and ammonium bicarbonate in rabbit must have caused contact toxicity to whitefly nymphs, hence their reduced numbers as explained by Durán-Lara *et al.* (2020). Moreover, since rabbit urine also repelled and killed the adult whiteflies, fewer nymphs were hatched from the fewer eggs laid by the adults. Moreover, plant scorching increased with increase in the concentration of rabbit urine foliar spray, hence higher whitefly nymph numbers in less scorched treatments as explained by Salam *et al.* (2012). Unlike all other higher rabbit urine concentrations, treatment 0% v/v rabbit urine (negative control) exhibited an increasing trend in the number of whitefly nymphs. As explained by Zayed *et al.* (2022), water sprays do not control whiteflies effectively. Therefore, this led to build-up of whitefly nymphs that hatched from the numerous eggs laid by the adults over time. The number of whitefly nymphs in treatment 0.1% v/v Duduthrin 1.75EC (positive control) decreased at first up to 70 DAT and there after started to increase. This trend was also shown by adult whiteflies, lowering the efficacy of the synthetic pesticide due to resistance development. This led to more nymphs hatching from the numerous eggs laid by the adults.

The number of whitefly eggs decreased with increase in the concentration of rabbit urine foliar spray. This automatically led to increase in the efficacy of rabbit urine against whitefly eggs with increase in rabbit urine spray concentration. The ammonia and ammonium bicarbonate in rabbit urine repelled and killed adult whiteflies, leading to reduced number of eggs laid. Additionally, plant scorching was higher in plots treated with higher rabbit urine concentrations. This therefore controlled adult whiteflies, leading to reduced rate of egg laying. Unlike all other higher rabbit urine concentrations, treatment 0% rabbit urine (negative control) exhibited an increasing trend in the number of whitefly eggs. Since there was no plant scorching in the negative control and the water sprays did not control the adult whiteflies effectively, egg laying intensified due to the increasing number of the adults over time. The reason as to why the number of whitefly eggs in treatment 0.1% v/v Duduthrin 1.75EC (positive control) increased at first and then started to increase could be due to resistance development by the adult whiteflies against the synthetic pesticide, leading to laying of more eggs by the adults. Therefore, this trend led to reduced efficacy of the synthetic pesticide against whitefly eggs.

Percent repellence (PR) increased with increase in the concentration of rabbit urine spray. Increasing the concentration of rabbit urine automatically increased the ammonia content, hence stronger pungent smell of the rabbit urine spray. Previous studies by Dias *et al.* (2019) suggest that pungent smell of ammonia increases with increase in rabbit urine concentration. Since 0.1% Duduthrin 1.75EC does not have ammonia like rabbit urine, the synthetic pesticide did not repel adult whiteflies as much as rabbit urine.

Within 48 hours, the concentration of rabbit urine required to kill 50% of adult whiteflies was lower than that of Duduthrin 1.75EC. This therefore means that rabbit urine controls whiteflies effectively and quicker than Duduthrin 1.75EC. The ammonium bicarbonate in rabbit urine kills whiteflies through contact toxicity (Lekamoi *et al.*, 2022).

5.2 Effect of Different Concentrations of Rabbit Urine Foliar Spray on Yield and Yield Components of Tomato

The number of flowers per plant increased with increase in rabbit urine spray concentration from 0% v/v to 40% v/v, after which the number started to decrease. Treatment 100% v/v rabbit urine gave the lowest number of flowers per plant. Although treatment 100% v/v rabbit urine controlled whitefly populations with the highest efficacy, its scorching effect on plant foliage was the highest among all treatments. Previous studies by Richert *et al.* (2011) and FAO (2012) suggest that undiluted rabbit urine foliar spray is toxic to plants since it leads to scorching of plant foliage. Therefore, the plant foliage scorching reduced the photosynthetic area of the plants, subsequently leading to lower flower formation. Hasanuzzaman *et al.* (2018) argued that reduced photosynthetic area of plants leads to poor flower setting. Treatments 0% rabbit urine (negative control) and 0.1% v/v Duduthrin 1.75EC (positive control) registered fewer numbers of flowers per plant than treatment 40% rabbit urine in both trials. Since whitefly populations decreased with increase in rabbit urine spray concentration, this led to treatment 40% v/v rabbit urine registering lower whitefly populations than both the positive and negative controls. Mutisya *et al.* (2016) reported that higher intensities of whitefly attacks weakens tomato plants; hence negatively affecting flower formation and fruit set.

The numbers of fruits per plant in treatments 18.2% v/v rabbit urine and 25% v/v rabbit were not significantly different from those in treatment 0.1% v/v Duduthrin 1.75EC (positive control). This could be due to the low degree plant foliage scorching observed in the three treatments. Although treatment 100% v/v rabbit urine recorded higher numbers of fruits formed per plant in most sampling days of trial 1, this treatment registered the lowest numbers of fruits formed per plant in most sampling days of trial 2. Since trial 2 was conducted in the same plots as trial 1, treatment 100% v/v rabbit urine must have caused soil salinization over time. FAO (2012) reported that undiluted rabbit urine contains large amounts of salts which can accumulate in the soil over time, leading to soil salinization over time and cause reduction in fruit formation. In both trials, plants in treatment 100% v/v rabbit urine formed fruits much earlier than plants in all the other treatments. Salinity stress leads to early fruit set in tomato plants (Zhang *et al.*, 2016).

Treatment 0% v/v rabbit urine (negative control) registered the highest numbers of small-sized fruits. This could be attributed to the build-up of whitefly populations due to the low efficacy of the negative control against whiteflies. High whitefly populations lead to the formation of sooty mold that covers leaf surfaces, hence reducing the plants photosynthetic area (Mutisya *et al.*, 2016). Sumaili *et al.* (2021) further explained that reduction in photosynthetic area of tomato plants led to production of small-sized fruits. Moreover, water sprays used in the negative control did not contain N, P and K. Therefore, plants in this treatment received less amounts of nutrients than those sprayed with higher rabbit urine concentrations.

Treatment 18.2% v/v rabbit urine recorded the highest numbers of medium and large-sized fruits in most sampling days of trial 1. In most sampling days of trial 2, treatment 25% v/v rabbit urine registered the highest numbers of medium and large sized fruits. Treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine controlled whitefly populations with higher efficacies than the negative control. Moreover, leaf scorching was less in these treatments and hence there was no reduction of plant photosynthetic area.

Treatment 18.2% v/v rabbit urine registered the highest number and weight of marketable fruits in trial 1. In trial 2, treatment 25% v/v rabbit urine recorded the highest number and weight of marketable fruits. Treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine supplied N, P and K to the plants and controlled whiteflies with higher efficacies than treatment 0% v/v rabbit urine. Mutisya *et al.* (2016) observed that the lower the whitefly population, the higher the marketable yield of tomato. Additionally, the degree of plant foliage scorching was low in treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine as compared to treatment 100% v/v rabbit urine. This therefore led to stronger plants that produced medium to large-sized fruits with no physical deformities like sooty mould covering. Treatment 100% v/v rabbit urine gave the highest marketable yield at 77 DAT of both trials. Chaudhary *et al.* (2020) reported that leaf scorching causes stress to plants and this triggers early maturity in plants to produce fruits as a stress response measure.

The number and weight of non-marketable fruits decreased with increase in the concentration of rabbit urine spray from 0% v/v to 25% v/v. Treatment 0% v/v rabbit

urine (negative control) recorded the lowest number and weight of non-marketable fruits in both trials. Although the negative control did not scorch plant foliage, its recorded increased populations of whiteflies over time. Moreover, unlike rabbit urine, water sprays used in the negative control do not add any nutritional value to the crops and this led to weaker plants. Sumaili *et al.* (2021) explained that high whitefly population leads to weakening of tomato plants through sap sucking and viral disease transmission. They also reported that the formation of sooty mould due to whitefly infestation reduces the photosynthetic area of the plants, hence increasing the non-marketable yield.

The non-marketable yield in treatment 0.1% v/v Duduthrin 1.75EC (lambda cyhalothrin) was higher in trial 2 than in trial 1. Ghosal *et al.* (2018) explained that synthetic chemicals like lambda cyhalothrin lead to pest resistance and eventually leading to higher pest population due to resurgence of the pests. This high population of whiteflies automatically leads to weak plants and sooty mould on fruits, hence increased non-marketable yield.

In both trials, treatment 100% v/v rabbit urine registered the lowest grand total yields. Although pure rabbit urine controlled whitefly populations with the highest efficacies, its high plant foliage scorching effect reduced tomato yield more than how higher whitefly populations affected yield from all other treatments. The grand total yield, in terms of fruit numbers and weights per hectare, from treatment 100% rabbit urine was lower in the second trial than in the first trial. This could be due high soil salinity caused by pure rabbit urine sprays over time. Machado and Serralheiro (2017) explained that accumulation of salts in the soil over time reduces tomato yield. Similarly, tomato yield in treatment 0% v/v rabbit urine (negative control) was lower in the second trial than in the first trial. Whitefly populations in the negative control increased rapidly over time since water sprays did not effectively control them. Very high whitefly populations lead to low tomato yield due to high viral disease spread and increased sooty mold production on plants by the pest (Sumaili *et al.*, 2021).

Treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine gave the highest yield in terms of fruit numbers and weights in both trials. Since these treatments consisted of weaker dilution levels of rabbit urine, the degrees of foliage scorching and soil salinization were lower than in plots sprayed with 100% v/v rabbit urine. Richert *et al.*

(2011) explained that diluting rabbit urine helped in minimizing cases of plant foliage scorching and salt accumulation in the soil. Moreover, treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine controlled whiteflies with higher efficacies compared to treatment 0% v/v rabbit urine (negative control). Treatment 40% v/v rabbit urine exhibited higher degrees of plant foliage burning than treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine. Soil salinity may also have been higher in treatment 40% v/v rabbit urine than in treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine since the rabbit urine concentration of the former was higher than that of the latter. Therefore, the yield from treatment 40% v/v rabbit urine was generally lower than yield from treatments 18.2% v/v rabbit urine and 25% v/v rabbit urine.

5.3 Effect of Different Concentrations of Rabbit Urine Foliar Spray on Tomato Post-harvest Quality

Fruit firmness decreased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 100% v/v. Treatment 100% recorded the lowest fruit firmness while treatment 0% v/v rabbit urine (negative control) registered the highest. 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. 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 in tomato. In the current study, fruit firmness decreased with increase in storage time. 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.

Fruit total soluble solids (TSS) and titratable acidity (TA) contents increased with increase in the concentration of rabbit urine foliar spray from 0% v/v to 100% v/v. Treatment 100% v/v rabbit urine registered the highest TSS and TA contents while treatment 0% v/v rabbit urine (negative control) registered the lowest. Similarly, higher rabbit urine concentration leads to higher the rate of salt accumulation in the soil. Fruit TSS and TA contents increase with increase in soil salinity (Ilahy *et al.*, 2022). Moreover, nitrogen content increases with increase in rabbit urine spray concentration (Mutai,

2020). Frías-Moreno *et al.* (2020) further explained that increasing nitrogen supply to tomato plants leads to increase in fruit TSS and TA contents. Fruit TSS content increased over storage time. However, fruit TA content decreased over storage time. Shehata *et al.* (2021) explained that fruit ripening is a process that involves increase in sugar content and decrease in acid content.

The sugar acid content of tomatoes decreased with increase in rabbit urine spray concentration from 0% v/v to 100% v/v. Treatment 100% v/v rabbit urine registered the lowest sugar acid ratio while treatment 0% v/v rabbit urine recorded the highest. In all treatments, sugar acid content increased over storage time. This is because as the total soluble solids increase, the titratable acidity decreases with ripening of the fruit (Yeshiwas & Tolessa, 2018).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the findings of this study, the following conclusions can be made:

- i. Rabbit urine foliar spray significantly reduces the populations of whitefly adults and nymphs and the number of whitefly eggs. Whitefly populations decrease with increase in rabbit urine spray concentration.
- ii. Rabbit urine foliar spray has significant effect on the yield and post-harvest quality of tomatoes. Treatment 25% v/v rabbit urine gives the highest yield due to optimal whitefly control, less plant foliage scorching and sufficient nutrient supply to the crop. Moreover, treatment 25% v/v rabbit urine registers considerably high fruit TSS and TA contents.
- iii. Rabbit urine has significant repellent and toxic effect on adult whiteflies. Repellence and mortality of adult whiteflies increases with increase in the concentration of rabbit urine foliar spray.

6.2 Recommendations

From the above conclusions, the following recommendations can be made:

- i. Farmers should adopt the use of rabbit urine at 25% v/v concentration, for eco-friendly management of whiteflies and increased yield and post-harvest quality of tomatoes.
- ii. Further research should be carried out to understand the bioactive principles behind the repellence and toxicity of rabbit urine against whiteflies and cost-effective and ecologically sound application regimes for optimal and quality tomato production.

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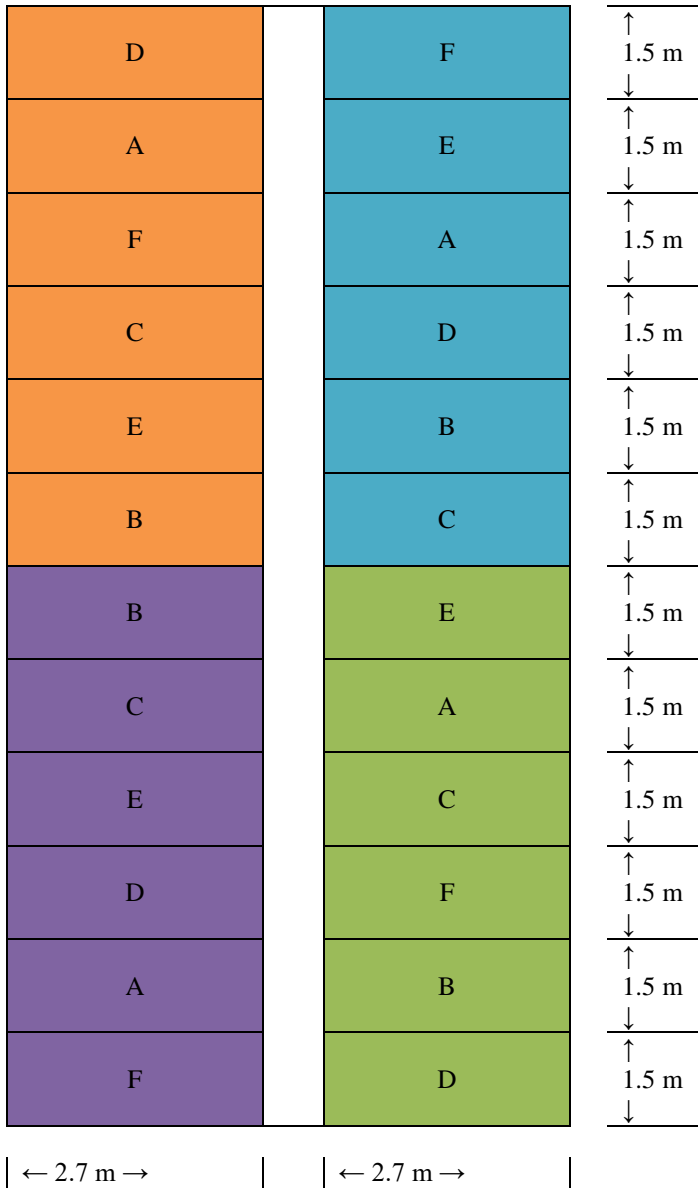
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APPENDICES

Appendix I: Experimental field layout in the greenhouse



where,

Block 1

Block 2

Block 3

Block 4

Appendix II: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on adult whitefly populations at week 11

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	5958.14318			
Block	3	121.08595	40.361983	2.71	
Treatment	5	5613.44718	1122.68944	75.31	<.0001
Error	15	223.61005	14.907337		
Coefficient of variation = 19.36					
Trial 2					
Total	23	5594.4891			
Block	3	43.280212	14.426737	2.71	
Treatment	5	5471.22057	1094.24411	205.2	<.0001
Error	15	79.988313	5.332554		
Coefficient of variation = 12.47					

Appendix III: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on whitefly nymph populations at week 11

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	59050.0365			
Block	3	376.93668	125.64556	2.56	
Treatment	5	57937.57077	11587.51415	236.31	<.0001
Error	15	735.52905	49.03527		
Coefficient of variation = 8.11					
Trial 2					
Total	23	31440.0714			
Block	3	15.3047	5.10157	0.75	
Treatment	5	31322.11535	6264.42307	915.39	<.0001
Error	15	102.65135	6.84342		
Coefficient of variation = 3.49					

Appendix IV: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on whitefly nymph populations ANOVA at week 11

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	90118.4169			
Block	3	1895.46075	631.82025	13.16	
Treatment	5	87502.5776	17500.5155	364.4	<.0001
Error	15	720.37858	48.02524		
Coefficient of variation = 7.74					
Trial 2					
Total	23	35370.8207			
Block	3	25.98958	8.66319	1.17	
Treatment	5	35233.9477	7046.78954	953.27	<.0001
Error	15	110.8834	7.39223		
Coefficient of variation = 3.12					

Appendix V: Summary ANOVA-Repellence of different concentrations of rabbit urine foliar spray against adult whiteflies

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	8	14.933333	1.866667		
Replication	2	14.4	7.2	3.86	
Treatment	4	1532.26667	383.066667	205.21	<.0001
Error	14	1561.6			
Coefficient of variation = 7.76					
Trial 2					
Total	14	1270.4			
Replication	2	1.6	0.8	0.26	
Treatment	4	1243.73333	310.933333	99.23	<.0001
Error	8	25.066667	3.133333		
Coefficient of variation = 10.54					

Appendix VI: Summary ANOVA-Toxicity of different concentrations of rabbit urine foliar spray on adult whiteflies

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	17	5584			
Replication	2	9.333333	4.666667	1.67	
Treatment	5	5546.666667	1109.333333	396.19	<.0001
Error	10	28	2.8		
Coefficient of variation = 4.05					
Trial 2					
Total	17	5385.777778			
Replication	2	11.111111	5.555556	2.66	
Treatment	5	5353.777778	1070.755556	512.6	<.0001
Error	10	20.888889	2.088889		
Coefficient of variation = 3.53					

Appendix VII: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on the total number of marketable fruits per hectare (no/ha)

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	6.15951E+11			
Block	3	70755137239	23585045746	2.62	
Treatment	5	4.10402E+11	82080464582	9.13	0.0004
Error	15	1.34793E+11	8986218380		
Coefficient of variation =6.99					
Trial 2					
Total	23	4.43E+12			
Block	3	4.67834E+11	1.55945E+11	7.16	
Treatment	5	3.63E+12	7.26542E+11	33.36	<.0001
Error	15	3.26669E+11	21777926429		
Coefficient of variation =11.21					

Appendix VIII: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on the total weight of marketable fruits per hectare (t/ha)

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	9591.036			
Block	3	1886.067	628.6891	6.91	
Treatment	5	6339.629	1267.926	13.93	<.0001
Error	15	1365.34	91.02265		
Coefficient of variation =8.27					
Trial 2					
Total	23	51931.59			
Block	3	4038.012	1346.004	4.5	
Treatment	5	43405.87	8681.174	29.02	<.0001
Error	15	4487.707	299.1804		
Coefficient of variation =15.62					

Appendix IX: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on the total number of non-marketable fruits per hectare (no/ha)

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	92863805201			
Block	3	17034120717	5678040239	3.88	
Treatment	5	53868812057	10773762411	7.36	0.0011
Error	15	21960872426	1464058162		
Coefficient of variation =34.12					
Trial 2					
Total	23	8.61445E+11			
Block	3	13533919532	4511306511	0.82	
Treatment	5	7.65855E+11	1.53171E+11	28	<.0001
Error	15	82056992422	5470466161		
Coefficient of variation =37.62					

Appendix X: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on the total weight of non-marketable fruits per hectare (t/ha)

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	681.5479			
Block	3	166.2646	55.42152	3.85	
Treatment	5	299.5833	59.91665	4.17	0.0142
Error	15	215.7001	14.38		
Coefficient of variation =60.65					
Trial 2					
Total	23	5682.739			
Block	3	535.4299	178.4766	2.33	
Treatment	5	3997.485	799.497	10.43	0.0002
Error	15	1149.824	76.65493		
Coefficient of variation =59.81					

Appendix XI: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on the grand total number of fruits harvested per hectare (no/ha)

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	7.03001E+11			
Block	3	1.31744E+11	43914705889	2.89	
Treatment	5	3.43487E+11	68697473556	4.52	0.0103
Error	15	2.27769E+11	15184628001		
Coefficient of variation =8.39					
Trial 2					
Total	23	4.13E+12			
Block	3	6.11875E+11	2.03958E+11	6.58	
Treatment	5	3.05E+12	6.10668E+11	19.7	<.0001
Error	15	4.6493E+11	30995328969		
Coefficient of variation =11.64					

Appendix XII: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on the grand total weight of fruits harvested per hectare (t/ha)

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	11042.07			
Block	3	3170.82	1056.94	10.14	
Treatment	5	6308.21	1261.642	12.11	<.0001
Error	15	1563.04	104.2026		
Coefficient of variation =8.43					
Trial 2					
Total	23	50399.64			
Block	3	6769.222	2256.407	6.43	0.0051
Treatment	5	38368.74	7673.747	21.88	<.0001
Error	15	5261.681	350.7788		
Coefficient of variation =14.94					

Appendix XIII: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on fruit firmness within 12 storage days

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	1.47958333			
Block	3	0.17125	0.05708333	12.92	
Treatment	5	1.24208333	0.24841667	56.25	<.0001
Error	15	0.06625	0.00441667		
Coefficient of variation =2.61					
Trial 2					
Total	23	1.35958333			
Block	3	0.15458333	0.05152778	5.23	
Treatment	5	1.05708333	0.21141667	21.44	<.0001
Error	15	0.14791667	0.00986111		
Coefficient of variation =3.79					

Appendix XIV: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on total soluble solids (TSS) content of tomato fruits within 12 storage days

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	1.95833			
Block	3	1.405	0.46833	108.08	
Treatment	5	0.48833	0.09767	22.54	<.0001
Error	15	0.065	0.00433		
Coefficient of variation =2.05					
Trial 2					
Total	23	1.23833			
Block	3	0.165	0.055	7.86	
Treatment	5	0.96833	0.19367	27.67	<.0001
Error	15	0.105	0.007		
Coefficient of variation =2.62					

Appendix XV: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on titratable acidity (TA) content of tomato fruits within 12 storage days

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	1.1E-05			
Block	3	2.85E-07	9.50E-08	0.93	
Treatment	5	9.52E-06	1.90E-06	18.7	<.0001
Error	15	1.5E-06	1E-07		
Coefficient of variation =5.69					
Trial 2					
Total	23	1.3E-05			
Block	3	5.2E-07	1.7E-07	1.85	
Treatment	5	1.1E-05	2.2E-06	23.94	<.0001
Error	15	1.4E-06	9E-08		
Coefficient of variation =5.46					

Appendix XVI: Summary ANOVA-Effect of different concentrations of rabbit urine foliar spray on sugar acid ratio (TSS/TA) of tomato fruits within 12 storage days

Sources	DF	Type III SS	MSE	F Value	Pr > F
Trial 1					
Total	23	78787.8			
Block	3	28693.4	9564.46	9.84	
Treatment	5	35510	7101.99	7.3	0.0012
Error	15	14584.5	972.301		
Coefficient of variation =5.40					
Trial 2					
Total	23	55560			
Block	3	12848.8	4282.92	4.62	
Treatment	5	28797.4	5759.48	6.21	0.0026
Error	15	13913.8	927.588		
Coefficient of variation =5.29					

Research Article

Response of Whitefly Population to Rabbit Urine Foliar Spray on Tomato (*Solanum lycopersicum* L.)

Elvis Kalonzo Mutua , Mariam Mwangi, Liu Gaoqiong, and Jane Nyaanga

Department of Crops, Horticulture and Soils, Egerton University, P.O. Box 536, Egerton 20115, Kenya

Correspondence should be addressed to Elvis Kalonzo Mutua; nimrodelvis@gmail.com

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Whiteflies greatly contribute to low yields and quality in tomato production. Continuous use of synthetic pesticides leads to whiteflies developing resistance to these pesticides. This research aimed at promoting the use of rabbit urine as a biopesticide against whiteflies in tomato production. Although rabbit urine is been used as a biopesticide against different pests, the best concentration to control whiteflies in tomato production is unknown. Six treatments compared in the two experiments of this study included: 2 L rabbit urine : 9 L water; 2 L rabbit urine : 6 L water; 2 L rabbit urine : 3 L water; 2 L rabbit urine : 0 L water; 0 L rabbit urine : 2 L water, and 20 mL Duduthrin 1.75EC : 20 L water. The first experiment was conducted in a randomized complete block design with six treatments and four blocks to investigate the effects of rabbit urine on the control of whitefly eggs, nymphs, and adults. The second experiment was conducted in a completely randomized design to determine the effect of rabbit urine on the bioactivity of adult whiteflies. Results indicated that plots treated with rabbit urine foliar spray registered reduced populations of whitefly eggs, nymphs, and adults, and lower LT_{50} values of repelling and killing compared to the negative control (0 L rabbit urine : 2 L water). However, a high ratio of rabbit urine caused significant scorching to tomato leaves. A solution of 2 L rabbit urine : 6 L water optimally controls whiteflies without scorching the plant foliage. Rabbit urine has both repelling and killing effects on whiteflies. In the future, further research can be conducted to investigate the effect of rabbit urine on populations of other important insect pests of tomato.

1. Introduction

plant and sucking phloem sap, hence weakening the plant and causing leaf and fruit distortion [8]. These pests also injure

Appendix XVIII: Published paper on objective three

International Journal of Horticultural Science 2024, 30: 54-61.
<https://doi.org/10.31421/ijhs/30/2024/14173>

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

Mutua, E. K., Mwangi, M. & Gaoqiong, L.

Department of Crops, Horticulture and Soils, Egerton University, P.O. Box 536, 20115, Egerton, Kenya
Author for correspondence: nimrodelvis@gmail.com

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.

Mutua, E. K., Mwangi, M., Gaoqiong, L. (2024): Effect of rabbit urine foliar spray on the yield and post-harvest quality of tomato (*Solanum lycopersicum* L.). International Journal of Horticultural Science 30: 54-61. <https://doi.org/10.31421/ijhs/30/2024/14173>


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 ~~most of the locally available synthetic pesticides have been~~

Appendix XIX: Research permit


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