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Research Article

Pests, Diseases, Growth and Yield of Tomato as Influenced by Variety and Cultivation Technology

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Abstract

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetables in the world. However, dearth of knowledge exists on cultivation technology that contributes to increased production of the crop. Meanwhile, low yielding varieties, high pests and diseases attacks, climate variability and poor soil fertility are among key production constraints that limit the increased production and productivity of tomato in Sierra Leone. A two-year field experiment was conducted at the School of Agriculture and Food Sciences experimental site during 2022 and 2023 to evaluate the effects of variety and cultivation technology (CT) on pests, diseases, growth, yield and productivity of tomato. The experiment was laid in a 2 × 4 factorial (i.e. two varieties of tomato, and four treatments: CT 1, CT 2, CT 3 and CT 4 known as control) arranged in a randomized complete block design (RCBD) with three replications. Results showed that organic (CT 1 and CT 2) and inorganic (CT 3) treatments had a positive impact on growth parameters of tomato. The CT 1 (chicken dung, mulching, and neem extract biopesticide) was most effective in promoting vegetative growth and higher fruit yield, while CT 2 (NPK 15:15:15, urea, promethrin herbicide, and chlorpyrifos pesticide) exhibited highest potency in reducing population and damage caused by diseases and pests. Findings demonstrate that improved variety and cultivation technology boost tomato tolerance to pests and diseases, as well as its growth and yield performances that could be exploited for increased production and fruit quality of the crop. The CT1 was the most effective, followed by CT 2, while CT 4 or control plots had the lowest performance. The outperformance of the organic treatments relative to the inorganic and control is suggested to be attributable to its nitrogen-rich components. Weed control was also established to be effective in both inorganic and CT 2 treatments. The findings suggest that the CT 1 should be promoted for sustainable tomato cultivation, prioritizing environmentally friendly methods for long-term success.

Keywords

Pests, Diseases, Management, Cultivation Technologies, Tomato Productio

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1. Introduction

Tomato (*Solanum lycopersicum* L.) holds global significance, closely trailing behind potato and sweet potato in cultivated area but leading as the most processed crop [1]. In Sierra Leone, the relatively low tomato yield does not reflect the crop's full potential; instead, factors such as limited access to high-quality seeds, inadequate fertilization, irrigation, and pest and disease control measures contribute to this scenario. To enhance both yield and quality, varietal selection, balanced fertilization, and effective pest and disease control are crucial [2]. Historically, conventional agriculture heavily relied on synthetic chemical pesticides and fertilizers to manage pests and diseases, boost productivity, and maximize profits. Despite being considered effective, these methods raised environmental and health concerns, posing threats to soil quality, human health, and fostering pesticide-resistant pests [3]. The increasing global interest in organic agriculture emphasizes sustainable and eco-friendly practices [4].

Organic manures present a viable alternative, being more accessible and cost-effective compared to chemical fertilizers [5]. Organic farming avoids synthetic inputs, advocating natural approaches to pest and disease management, including crop rotation, biological control, and the use of organic manures. These practices aim to maintain ecological balance in agricultural systems while ensuring soil and ecosystem health and fertility that results in higher yield and quality of crops. Organic fertilizers contribute essential nutrients, vitamins, growth promoters, and beneficial microorganisms, resulting in improved growth, higher yields, and enhanced crop quality [6, 7]. Various organic manures, such as cow dung, poultry manure, goat manure, farmyard manure, compost, vermicompost, and mustard oil cake, are commonly employed in tomato production. For instance, cow dung, when applied in combination with chemical fertilizers, significantly boosts tomato growth and yield [8]. Organic manure enhances soil nutrient content and structure as well as contributing in improving yields of crops [9]. Although organic manures may result in lower yields compared to inorganic fertilizers, a combined approach allows the maximization of organic resources while reducing dependence on costly inorganic fertilizers [10, 11].

Amending agricultural soils with organic matter increases natural suppression of soil-borne pathogens through increasing beneficial microbes which creates biological competition and antagonism, and improves physicochemical of the soil [12]. Among the soil organic amendments that have been noted to improve soil properties as well as be effective in suppressing soil borne diseases and pathogens are wedelia [13], devil weed [14], cabbage waste [15], chicken dung [16], sunflower [17] and carbonized rice hull [18].

This study hypothesizes that integrating both organic and inorganic fertilizers can effectively control pests and diseases, enhance crop growth, yield, quality and productivity, and improve soil health. The present study evaluated the performances of two tomato varieties under different agronomic management strategies for their response to insects, weeds, diseases, growth and yield of tomato.

2. Materials and Methods

2.1. Description of the Experimental Site

A two-year (2022 and 2023) experiment was conducted at the School of Agriculture and Food Sciences experimental site, Njala University, Njala Campus, Sierra Leone to evaluate the effects of organic and inorganic management practices on pest, disease, weeds and the production and productivity of tomato. Njala University, Njala Campus is located in the Kori Chiefdom, Moyamba District Southern Sierra Leone. The campus, positioned at an elevation of 5 m above sea level on latitude 8° 06′N and longitude 12° 06′W, is about 114 miles from the capital city, Freetown. The landscape is predominantly covered with secondary bush, featuring a well-balanced mixture of sand, clay, and humus. The experimental site is densely covered with elephant grass, spear grass, and sedges, and situated relatively close to the swamp.

Njala University, Njala Campus, experiences distinct dry and wet seasons, with the rainy season spanning from April to November and the dry season from October to May. The mean monthly air temperature ranges from 21℃ to 23℃ during the greater part of the day and night, particularly in the rainy season. The soil of the experimental site belongs to the Njala University, Njala Campus soil series (*Orthoxic palehumult*). Prior to conducting the experiments, soil samples were collected at a 20 cm depth using a soil auger at different points within the site to assess the physical and chemical parameters (Table 1). Soil analysis revealed that the nitrogen levels were considerably low compared to phosphorus and potassium. The soils were generally low in moisture, have a low nutrient status and highly acidic in both 2022 and 2023, which are below the optimum pH of 6.5 (Table 1).

Table 1. Physico-chemical properties of soils of the experimental site for 2022 and 2023 cropping seasons.

Properties	Sampling in 2022		Sampling in 2023	
	Before planting	After harvesting	Before planting	After harvesting
Soil pH (1:1H_2O)	3.9	3.8	3.7	3.7
Soil pH (1:1KCl)	4.2	4.5	4.5	4.5
Nitrogen (N)	1.4	1.9	1.6	2.0
Phosphorus (P)	18.0	19.0	17.0	19.0
Potassium (K)	9.4	9.7	8.1	8.8

2.2. Experimental Materials, Treatments, Design, Layout and Management

The experimental materials were botanic seeds of two varieties of tomato including Heirloom (improved) and Nornro (local). The seeds were acquired from the Central Agricultural Research Institute (CARI), Monrovia, Liberia. The seeds were first raised in a nursery at the Crop Protection Department, NU, Njala Campus, Sierra Leone for four weeks before transplanting.

The treatments involved two varieties of tomato (Heirloom and Nornro) and four cultivation technologies including cultivation technology 1 (CT 1), cultivation technology 2 (CT 2), cultivation technology 3 (CT 3) and control or cultivation technology 4 (CT 4). The CT 1 involved the use of chicken manure (CM) at 5 t ha^{-1}, mulching and neem biopesticide. After incorporation CM, the manure was left to decompose for two weeks before transplanting. Mulching was applied one week after transplanting to prevent pest emergence. When pests and diseases appeared, a neem kernel extract was prepared from dried neem. The extract was prepared by dissolving 180 g neem powder and 5 g local soap in 1 L water, left to ferment for about a week and then applied. The CT 2 included locally prepared biofertilizer mango fertilizer (6 Lha^{-1}), hand weeding at one, two, and three weeks after transplanting (WAT), and neem extract in aqueous form (AZAGRO 3000) applied at 30 ml 6 L H_20^{-1} ha^{-1}. The CT 3 comprised the application of pre-emergence herbicide promithrine at 6 ml 6 L H_20^{-1} ha^{-1} at two weeks before transplanting (WBT), NPK 15:15:15 fertilizer application at 88.9 kg ha^{-1}, applied 1 WAT, and chlorpyrifos application at 6 ml 6 L H_20^{-1} ha^{-1} when diseases and pests attacked the plants). The CT 4 is the control treatment represented the conventional farming practices with no additional organic or inorganic inputs.

The experiment was laid in a 2 × 4 factorial arrangement implemented in a Randomized Complete Block Design (RCBD) with three replications. The plot size was 3 m × 5.25 cm (15.75 m^2).The experimental field was manually cleared of vegetation and thoroughly ploughed to a depth of about 10-15 cm and leveled using hoes and shovels. Transplanting was done in the evening using four weeks old tomato seedlings at a spacing of 75×75 cm (35,556 plants ha^{-1}). The ball of earth method of transplanting was used.

2.3. Data Collection

Growth, parameters collected plant height and number of branches) were measured from ten randomly selected and tagged plants in each plot from the middle rows using a measuring tape from the soil surface to the tip of the plants at 2,4 and 6 WAT, whilst the number of trusses and fruits was counted at every harvest from ten randomly selected tagged plants in each plot. The total number of fruits obtained from the selected plants was divided by the total number of plants tagged, to get the average number of fruits per plant.

$$\text{No. of fruits per plant} = \frac{\text{Total no.of fruits from ten hills}}{10}$$

At harvest the weight of the total number of fruits from ten tagged plants for each plot was recorded using a digital balance. The fresh fruit per plant was determined by dividing the total weight of the fruits by 10.

$$\text{Fresh fruits wt. per plant} = \frac{\text{Total no.of fresh fruits}}{10}$$

The insect pest population was determined on randomly selected and tagged 10 plants from the middle rows per plot at 2 and 4 WAT. The number of insects per plant was estimated by dividing the total number of insects by 10.

$$\text{No. of insects per plant} = \frac{\text{Total no.of insects on 10 plants}}{10}$$

The percentage leaf damage per plot by insects was determined by dividing the total percentage of leaf damage from the 10 selected plants by 10 and multiplying it by 100.

$$\text{Percent leaf damage} = \frac{\text{Leaf damage by insects}}{10} \times 100$$

The incidence of diseases was calculated as the percentage of diseases symptomatic plants out of the total of ten plants assessed using the formula provided by Sseruwagi *et al.* [19].

$$\text{Mean incidence (\%)} = \frac{\sum \text{Infected plants}}{\sum \text{plants}} \times 100$$

The severity of diseases was calculated from ten randomly selected plants using a scale 1-5 as provided by Sseruwagi *et al.* [19].

The weed populations in the field were evaluated at 2 and 4 WAT. A quadrat measuring 0.5 m^2 was randomly placed in each plot and thrown twice for collection of weeds. The weeds within the sampled area of the quadrat were then identified and counted. The harvested weed biomass per plot was subsequently oven-dried at 80 ℃ for 48 h before reweighing, until a constant weight was obtained. This process ensured accurate measurements of the weed biomass.

2.4. Data Analysis

Data were subjected to analysis of variance (ANOVA) using the GENSTAT statistical program (GENSTAT, 15th release, Rothampstead, UK). The Student Newman-Keuls (SNK) multiple range test was used to compare between treatment means using a significance level of α = 0.05. The residuals of data for the parameters were first checked for normality and homogeneity using the Shapiro-Wilk test and Bartlett's test to ensure that data are normally distributed.

3. Results and Discussion

3.1. Effects of Variety and Agronomic Management Practice on Growth of Tomato

Variety, agronomic management treatment, and variety × treatment interactions significantly (P ≤ 0.05) influenced growth (plant height and number of branches) of tomato plants (Table 2). For plant height, the improved variety consistently exhibited the highest measurements at 2 and 4 weeks after planting (WAT) in both years. In 2022, the improved variety reached 29.2 cm and 39.6 cm, while in 2023, the plants were 27.2 cm and 42.8 cm tall at 2 and 4 WAT, respectively. In contrast, the local variety produced shorter plants at 2 WAT (22.6 cm and 24.8 cm) and 4 WAT (37.8 cm and 40.0 cm) for both years, respectively. The CT 1 treated plots consistently recorded tallest plants for the improved variety at 2 WAT (30.33 cm and 38.43 cm) and 4 WAT (50.53 cm and 54.33 cm) in 2022 and 2023, respectively. Similar trends were observed for the local variety in terms of plant height.

Table 2. *Growth of tomato as affected by variety and cultivation technology during 2022 and 2023 cropping seasons.*

Treatment	2022				2023			
	Plant height (cm)		Number of branches plant^{-1}		Plant height (cm)		Number of branches plant^{-1}	
	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP
Variety								
Improved (Heirloom)	29.2±2. 0^a	39.6±2.1^a	0.0±0.0^a	1.4±0.0^a	27.2±1.3^a	42.8±3.0^a	0.0±0.0^a	0.8±0.0^a
Local (Nornro)	22.6±1.3^a	37.8±2.4^b	1.1±0.0^b	5.9±0.1^b	24.8±2.0^b	40.0±2.6^b	1.9±0.0^b	6.4±0.3^b
CT 1 Heirloom	30.3±2.3^a	50.5±2.2^a	0.0±0.0^c	1.8±0.1^c	38.4±1.0^a	54.3±0.6^a	0.0±0.0^c	1.3±0.3^d
CT 1 Nornro	30.2±1.6^a	46.7±0.9^b	2.3±1.0^a	13.3±2.9^a	30.6±2.0^{ab}	49.0±1.6^{ab}	3.0±2.0^a	15.0±2.1^a
CT 2 Heirloom	25.2±0.3^b	46.1±1.5^b	0.0±0.0^c	1.6±0.4^c	30.2±0.9^{ab}	48.0±0.4^{ab}	0.0±0.0^c	1.0±0.0^d
CT 2 Nornro	24.0±1.0^b	44.9±0.9^b	1.1±1.3^b	5.0±2.0^b	28.7±0.9^b	47.3±0.9^b	2.0±2.0^b	6.0±2.1^b
CT 3 Heirloom	20.9±1.6^c	33.7±2.0^c	0.0±0.0^c	1.4±0.9^c	24.9±1.4^c	39.7±2.4^c	0.0±1.0^c	1.0±1.0^d
CT 3 Nornro	20.3±0.9^c	32.8±2.0^c	1.0±0.2^b	3.7±1.5^b	25.3±1.0^c	35.2±0.6^d	1.6±0.3^b	2.3±1.9^c
CT 4 Control Heirloom	17.0±2.5^d	27.9±3.0^d	0.0±0.0^c	1.0±0.6^c	15.4±3.0^d	29.5±3.7^e	0.0±0.0^c	0.0±0.0^e
CT 4 Control Nornro	16.1±2.0^d	27.4±3.0^d	1.0±0.5^b	2.1±0.9^c	14.9±2.7^d	29.1±4.0^e	1.0±0.2^b	2.7±1.2^c
F-Statistic								
Treatment (Pr> F)	0.020	0.05	0.047	<0.001	<0.001	<0.001	<0.001	<0.001

Treatment	2022				2023			
	Plant height (cm)		Number of branches $plant^{-1}$		Plant height (cm)		Number of branches $plant^{-1}$	
	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP
Variety (Pr> F)	ns	0.05	<0.001	<0.001	0.05	0.05	<0.001	<0.001
Treatment × Variety (Pr> F)	ns	0.05	0.03	<0.001	0.05	0.04	0.02	<0.001
CV (%)	12.4	18.0	11.3	14.5	12.0	20.3	10.0	11.0

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; CT=cultivation technology; CV=coefficient of variation

For the number of branches, the local variety consistently showed significantly higher numbers of branches at 2 WAT (1.1 and 1.9 $plant^{-1}$) and 4 WAT (5.9 and 6.4 $plant^{-1}$) for both years compared to the improved variety. The CT 1 treated plot recorded the highest number of branches for both local and improved varieties at different sampling regimes. Overall, treated plots, especially those with organic treatments, produced significantly taller plants and higher numbers of branches compared to control plots. Furthermore, the number of branches in the 2023 cropping season was higher than in the previous year (2022). These findings indicate significant influence of variety and treatment application on plant growth characteristics, suggesting potential strategies for optimizing plant development in tomato cultivation.

3.2. Inventory of Weed Pests and Diseases of Tomato Identified

In both 2022 and 2023 evaluation periods, whitefly, aphid and leaf miner were the major insect pests identified in the field; whilst the major weeds found were *Imperata cylindrica*, *Croton hirtus* and *Diodia scandens*, and the major diseases identified were tomato mosaic and late blight (Table 3).

Table 3. *Inventory of pest, weeds and diseases on tomato.*

Name of insect pest	Status	Name of weed pest	Status	Name of disease	Status
Whitefly	Present	*Imperata cylindrica*	Present	Tomato mosaic disease	Present
Aphid	Present	*Croton hirtus*	Present	Late blight	Present
Leaf miner	Present	*Diodia scandens*	Present	Septoria leaf spot	Absent
Gram pod borer	Absent			Anthracnose fruit rot	Absent
Tobacco caterpillar	Absent				
Spider mites	Absent				

3.3. Effects of Variety and Cultivation Technology on Number and Percentage Damage of Tomato by Insect Pests

Whitefly and leaf miner populations and damages significantly ($P \leq 0.05$) varied among agronomic management treatments, with no notable interactions between variety and treatment at both 2 and 4 weeks after planting (Tables 4 and 5). Across both years, the local variety consistently exhibited lower whitefly counts at 2 weeks after transplanting (WAT) (7.8 and 8.0 $plant^{-1}$) and at 4 WAT (2.7 and 4.5 $plant^{-1}$) regardless of treatment, compared to the improved variety at 2 WAT (8.6 and 8.1 $plant^{-1}$) and at 4 WAT (2.9 and 4.6 $plant^{-1}$). In 2022 and 2023, inorganic treatment plots consistently recorded the lowest whitefly counts for both improved and local varieties at 2 WAT (4.00 and 4.09 $plant^{-1}$) and at 4 WAT (0.00 and 0.00 $plant^{-1}$). The CT 1 treated plot for both varieties showed higher whitefly counts compared to inorganic treatments but were lower than control plots. Notably, whitefly populations were lower in 2022 across all evaluation periods compared to 2023.

***Table 4**. Effects of variety and cultivation technology on the population and percentage damage of whitefly in 2022 and 2023 cropping seasons.*

Treatment	2022				2023			
	Number of whiteflies plant^{-1}		Leaf damage by whiteflies (%)		Number of whiteflies plant^{-1}		Leaf damage by whiteflies (%)	
	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP
Variety								
Improved (Heirloom)	8.6±0.5^{a}	2.9±0. 0^{a}	6.5±0.0^{a}	2.5±0.0^{a}	8.1±0.6^{a}	4.6±0.2^{a}	7.5±0.3^{a}	5.3±0.4^{a}
Local (Nornro)	7.8±0.4^{a}	2.7±0.0^{a}	6.4±0.0^{a}	2.5±0.0^{a}	8.0±0.5^{a}	4.5±0.2^{a}	7.4±0.5^{a}	5.2±0.4^{a}
CT 1 Heirloom	7.5±1.5^{b}	2.0±0.5^{b}	5.6±0.0^{b}	0.0±0.0^{b}	8.0±0.5^{b}	3.0±0.5^{b}	7.0±2.0^{b}	5.3±3.3^{b}
CT 1 Nornro	8.0±1.0^{b}	2.0±0.0^{b}	5.0±0.0^{b}	0.0±0.0^{b}	8.6±0.0^{b}	3.0±0.0^{b}	7.0±2.6^{b}	5.1±1.7^{b}
CT 2 Heirloom	8.2±1.6^{b}	2.6±0.7^{b}	5.4±0.6^{b}	0.0±0.0^{b}	9.1±0.7^{b}	3.7±0.6^{b}	7.7±2.0^{b}	6.0±1.7^{b}
CT 2 Nornro	8.9±1.6^{b}	2.0±0.6^{b}	5.8±0.2^{b}	0.0±0.0^{b}	9.0±0.6^{b}	3.0±0.2^{b}	8.0±1.9^{b}	5.7±1.7^{b}
CT 3 Heirloom	4.0±1.3^{c}	0.0±0.0^{c}	5.0±1.6^{b}	0.0±0.0^{b}	4.6±0.3^{c}	0.0±0.0^{c}	5.4±1.6^{c}	0.0±0.0^{c}
CT 3 Nornro	4.1±1.0^{c}	0.0±0.0^{c}	5.0±0.0^{b}	0.0±0.0^{b}	4.1±0.1^{c}	0.0±0.0^{c}	5.2±1.0^{c}	0.0±0.0^{c}
CT 4 Control Heirloom	10.5±1.6^{a}	7.0±0.7^{a}	10.0±0.3^{a}	10.0±1.5^{a}	11.0±1.6^{a}	12.7±1.3^{a}	10.0±2.0^{b}	10.0±1.9^{a}
CT 4 Control Nornro	10.3±1.8^{a}	7.0±0.5^{a}	10.0±0.2^{a}	10.0±1.1^{a}	11.0±1.7^{a}	12.3±1.5^{a}	10.0±2.0^{b}	10.0±2.0^{a}
F-Statistic								
Treatment (Pr> F)	0.05	<0.001	<.001	<.001	<.001	<.001	0.044	<.001
Variety (Pr> F)	ns	ns	ns	ns	ns	ns	ns	ns
Treatment × variety (Pr> F)	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	19.0	12.2	10.4	8.3	13.8	9.0	13.0	10.0

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; AMP=agronomic management practice; CV=coefficient of variation

***Table 5**. Effects of variety and cultivation technology on the population and percent leaf damage by leaf miner in 2022 and 2023 cropping seasons.*

Treatment	2022				2023			
	Number of leaf miner plant^{-1}		Leaf damage by leaf miner (%)		Number of leaf miner plant^{-1}		Leaf damage by leaf miner (%)	
	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP
Variety								
Improved (Heirloom)	4.8±0.0^{a}	2.6±0.0^{a}	20.0±1.6^{a}	11.2±0.7^{a}	5.6±0.5^{a}	2.7±0. 0^{a}	23.6±2.0^{a}	11.3±0.5^{a}
Local (Nornro)	4.9±0.0^{a}	2.7±0.0^{a}	20.0±1.6^{a}	11.3±0.7^{a}	5.8±0.5^{a}	2.7±0.0^{a}	24.1±1.2^{a}	11.5±0.6^{a}
CT 1 Heirloom	4.3±0.6^{b}	2.5±0.6^{b}	20.0±2.7^{b}	10.0±1.7^{b}	5.3±0.6^{ab}	2.3±0.6^{b}	25.0±2.9^{b}	10.0±2.9^{b}
CT 1 Nornro	4.3±1.52^{b}	2.3±0.5^{b}	20.1±2.3^{b}	10.1±1.3^{b}	5.3±1.5^{ab}	2.3±1.5^{b}	21.7±4.4^{c}	10.7±4.4^{b}
CT 2 Heirloom	5.7±0.6^{ab}	2.9±0.1^{b}	20.0±2.7^{b}	10.0±1.7^{b}	5.7±0.6^{ab}	2.7±0.6^{b}	25.0±2.9^{b}	10.0±2.9^{b}
CT 2 Nornro	6.3±1.2^{a}	2.8±0.2^{b}	20.1±2.3^{b}	10.1±1.3^{b}	6.3±1.2^{a}	2.3±1.2^{b}	25.7±6.7^{b}	10.7±6.6^{b}

Treatment	2022				2023			
	Number of leaf miner plant^{-1}		Leaf damage by leaf miner (%)		Number of leaf miner plant^{-1}		Leaf damage by leaf miner (%)	
	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP
CT 3 Heirloom	2.7 ±0.6^{c}	0.0 ±0.0^{c}	10.0 ±0.0^{c}	5.0 ±0.0^{c}	4.7 ±0.6^{b}	0.7 ±0.0^{c}	10.1 ±0.0^{d}	5.0 ±0.0^{c}
CT 3 Nornro	2.3 ±1.5^{c}	0.0 ±0.0^{c}	10.0 ±0.0^{c}	5.0 ±0.0^{c}	4.3 ±0.5^{b}	0.3 ±0.0^{c}	10.1 ±5.0^{d}	5.0 ±5.0^{c}
CT 4 Control Heirloom	7.0 ±0.0^{a}	6.0 ±0.0^{a}	30.3 ±3.0^{a}	20.3 ±3.0^{a}	7.2 ±0.0^{a}	6.0 ±0.0^{a}	38.3 ±6.0^{a}	20.3 ±6.0^{a}
CT 4 Control Nornro	7.0 ±1.7^{a}	6.0 ±1.7^{a}	30.0 ±3.0^{a}	20.0 ±3.0^{a}	7.3 ±1.7^{a}	6.0 ±1.7^{a}	35.0 ±7.6^{ab}	20.0 ±7.6^{a}
F-Statistic								
Treatment(Pr> F)	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Variety(Pr> F)	ns	ns	ns	ns	ns	ns	ns	ns
Treatment ×Variety(Pr> F)	ns	ns	ns	ns	ns	ns	ns	ns
Treatment × Year(Pr> F)	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	17.6	10.0	14.8	10.0	16.9	8.3	16.0	14.7

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; AMP=agronomic management practice; CV=coefficient of variation

Similarly, treatments significantly influenced the percentage damage caused by whiteflies over the two evaluation years, with no significant Varietal or Variety × Treatment interactions at 2 and 4 weeks after planting. The local variety consistently exhibited lower percentage damage at both 2 WAT (6.4 and 7.4%) and 4 WAT (2.5 and 5.2%) compared to the improved variety. Inorganic treatments consistently resulted in the lowest percentage leaf damage for both varieties, followed by CT 1 treatment. Control plots consistently had the highest percentage leaf damage for both varieties, with higher damage observed in 2023 compared to 2022. This study highlights the significant impact of treatments on whitefly populations and associated damage, with inorganic treatments showing the most effective control measures. Additionally, the local variety displayed greater resistance to whiteflies compared to the improved variety across both years.

The improved variety consistently exhibited lower leaf miner counts at 2 WAT (4.8 and 5.6 plant^{-1}) and at 4 WAT (2.6 and 2.7 plant^{-1}) compared to the local variety. Inorganic treated plots consistently showed the lowest leaf miner counts, followed by CT 1 treated plot. However, control plots consistently exhibited the highest leaf miner counts for both varieties throughout both evaluation years (2022 and 2023), indicating the inefficacy of control methods in managing leaf miner populations.

The improved variety consistently demonstrated lower percentage leaf damage at both 2 WAT (20.0 and 23.6%) and 4 WAT (11.2 and 11.3%) compared to the local variety. Inorganic treated plots resulted in the lowest percentage leaf damage, while control plots consistently exhibited the highest percentage leaf damage for both varieties in both evaluation years. This study underscores the effectiveness of treatments in managing leaf miner populations and associated damage, with inorganic treatments showing the most promising outcomes. Additionally, the improved variety showcased greater resistance to leaf miners compared to the local variety across both evaluation years.

For aphid population, the local variety consistently had lower leaf aphid counts at 2 WAT (3.8 and 4.3 plant^{-1}) and at 4 WAT (2.3 and 1.9 plant^{-1}) compared to the improved variety (Table 6). Inorganic treated plots had the lowest leaf aphid counts, followed by CT 1 treated plots, across both years. However, control plots consistently exhibited the highest aphid numbers for both varieties throughout the two years of evaluations (2022 and 2023), indicating the inefficacy of control methods in managing aphid populations.

Table 6. *Effects of variety and cultivation technology on the population and percentage damage of leaf by aphid in 2022 and 2023 cropping seasons.*

Treatment	2022				2023			
	Number of aphid plant^{-1}		Leaf damage by aphid (%)		Number of aphid plant^{-1}		Leaf damage by aphid (%)	
	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP
Variety								
Improved (Heirloom)	4.0±0.1^a	2.4±0.2^a	11.4±0.4^a	0.0±0.0^a	4.3±0.3^a	2.2±0.1^a	12.9±1.8^a	5.1±0.3^a
Local (Nornro)	3.8±0.1^a	2.3±0.1^a	11.4±0.4^a	2.7±0.1^b	4.3±0.3^a	1.9±0.0^a	13.2±1.9^a	5.2±0.3^a
CT 1 Heirloom	3.0±1.9^c	1.0±0.9^b	10.1±0.9^b	0.0±0.0^b	2.3±1.9^d	1.3±0.9^b	10.2±2.9^d	5.0±0.4^b
CT 1 Nornro	3.0±0.9^d	1.0±0.1^b	10.3±0.7^b	0.0±0.0^b	2.6±0.9^d	1.2±0.1^b	8.3±1.7^e	5.3±0.7^b
CT 2 Heirloom	3.6±0.9^d	1.6±0.9^b	10.7±0.7^b	0.5±0.0^b	2.7±0.9^d	1.7±0.1^b	11.7±1.7^d	5.7±0.5^b
CT 2 Nornro	3.3±1.2^c	1.1±0.2^b	10.3±0.7^b	0.5±0.0^b	4.3±1.2^c	1.3±0.02^b	13.3±1.7^c	5.3±0.4^b
CT 3 Heirloom	2.7±0.9^c	0.0±0.0^c	10.0±0.7^b	0.0±0.0^c	2.1±0.9^d	0.6±0.0^c	8.0±1.7^e	0.0±0.0^c
CT 3 Nornro	2.0±0.6^b	0.0±0.0^c	10.0±0.9^b	0.0±0.0^c	2.0±0.6^d	0.0±0.0^c	10.0±2.9^d	0.0±0.0^c
CT 4 Control Heirloom	7.3±0.9^a	7.3±0.9^a	15.0±1.3^a	10.3±0.3^a	8.3±0.9^a	5.3±0.5^a	23.3±3.3^a	10.3±1.3^a
CT 4 Control Nornro	7.3±1.2^a	7.3±1.2^a	15.0±1.9^a	10.0±0.9^a	8.3±1.2^a	5.3±0.2^a	20.0±2.9^b	10.0±1.9^a
F-Statistic								
Treatment (Pr> F)	0.05	<0.001	<.001	<.001	<.001	<.001	<.001	<.001
Variety(Pr> F)	ns	ns	ns	<.001	ns	ns	ns	ns
Treatment × variety	ns	ns	ns	<.001	ns	ns	ns	ns
Treatment × year	ns	ns	ns	<.001	ns	ns	ns	ns
CV (%)	9.7	10.6	14.0	18.4	16.3	10.4	20.1	22.0

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; ns = non-significant at 5% SNK; CT=cultivation technology; CV=coefficient of variation

Regarding percentage leaf damage caused by aphids, treatments significantly influenced it during both evaluation years (P ≤ 0.05), with significant interactions observed at 4 WAT in 2022 (P ≤ 0.05). The improved variety consistently showed lower percentage leaf damage at both 2 WAT (11.4 and 12.9%) and 4 WAT (0.0 and 5.1%) compared to the local variety. Inorganic treated plots resulted in the lowest percentage leaf damage, while control plots consistently exhibited the highest percentage leaf damage for both varieties in both evaluation years. Overall, the study highlights the significant impact of treatments on leaf aphid populations and associated damage, with inorganic treatments showing promising results. Additionally, the improved variety displayed greater resistance to leaf aphids compared to the local variety across both evaluation years.

3.4. Effects of Variety and Cultivation Technology on Incidence and Severity of Diseases

The study found significant treatment effects on tomato mosaic disease incidence during both evaluation years (P ≤ 0.05), with significant interactions at 2 WAT in 2023 (Table 7). The local variety consistently had lower incidence at 2WAT (20.8 and 20.2%) and 4 WAT (16.4%) compared to the improved variety (21.3 and 22.5% at 2 WAT, 16.5 % at 4 WAT). Inorganic treatments consistently showed lower incidence at 2 (10.7 and 10.3%) and 4 WAT (5.7 and 5.3%) in 2022, and at 2 (10.6 and 10.0%) and 4 WAT (5.7 and 5.3%) in 2023. Overall, disease incidence decreased in 2023 compared to 2022, with control plots consistently showing the highest incidence. For disease severity, treatments significantly influenced it during both years (P ≤ 0.05), with no significant interactions at 2 and 4 WAT. The local variety consistently had lower severity at 2 WAT (2.7) and 4 WAT (1.8 and 2.0) compared to the improved variety (2.8 and 2.7 at 2 WAT, 1.8 and 2.1 at 4 WAT). Inorganic treatments consistently showed lower severity at 2 (2.0) and 4 WAT (1.0) in 2022, and at 2 (2.1) and 4 WAT (1.6) in 2023. Control plots consistently exhibited the highest severity values of 2.0 and 4.3 at 2 and 4 WAT in 2022, respectively. Overall, severity increased in 2023 compared to 2022.

Table 7. *Effects of variety and cultivation on the incidence and severity of tomato mosaic disease.*

Treatment	2022				2023			
	Incidence		Severity		Incidence		Severity	
	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP
Variety								
Improved (Heirloom)	21.3±0.1 a	16.5±1.0a	2.8±0.1a	1.8±0.1 a	22.5±1.1a	16.5±0.6 a	2.7±0.1a	2.1±0.2a
Local (Nornro)	20.8±0.1a	16.4±1.0a	2.7±0.2a	1.8±0.1a	20.2±1.2a	16.4±0.6a	2.7±0.1a	2.0±0.0a
CT 1 Heirloom	22.0±0b	10.0±0b	2.5±0.0b	1.0±0.1b	20.0±0b	10.0±0b	2.5±0.0b	1.5±0.1b
CT 1 Nornro	22.3±2.3b	10.3±3.3b	2.5±0.0b	1.0±0.1b	20.3±2.3b	10.3±3.3b	2.5±0.0b	1.4±0.1b
CT 2 Heirloom	22.0±2.9b	10.0±2.9b	2.7±0.3b	1.0±0.3b	20.0±2.9b	10.0±2.9b	2.7±0.3b	1.7±0.3b
CT 2 Nornro	20.7±1.3b	10.7±3.3b	2.5±0.3b	1.0±0.3b	10.7±1.3c	10.7±3.3b	2.5±0.32b	1.3±0.3b
CT 3 Heirloom	10.7±1.3c	5.7±3.3c	2.0±0.3b	1.0±0.3b	10.6±1.3c	5.7±3.3c	2.1±0.3b	1.6±0.3b
CT 3 Nornro	10.3±1.3c	5.3±3.3c	2.0±0.3b	1.0±0.3b	10.0±1.3c	5.3±3.3c	2.1±0.3b	1.6±0.3b
CT 4 Control Heirloom	30.7±1.3a	40.0±3.3a	4.0±0.0a	4.3±0.0a	39.7±1.3a	40.0±3.3a	4.0±0.0a	4.0±0.0a
CT 4 Control Nornro	30.0±0.0a	40.0±0.0a	4.0±0.0a	4.3±0.0a	40.0±0.0a	40.0±0.0a	4.0±0.0a	4.0±0.0a
F-Statistic								
Treatment (Pr> F)	<.001	<0.001	0.05	<.001	<.001	<.001	<.001	<.001
Variety (Pr> F)	ns	ns	ns	ns	0.05	ns	ns	ns
Treatment × variety	ns	ns	ns	ns	0.05	ns	ns	ns
Treatment × year	ns	ns	ns	ns	0.05	ns	ns	ns
CV (%)	16.5	11.0	10.4	7.6	18.9	22.3	10.0	8.9

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; ns = non-significant at 5% SNK; CT=cultivation technology; CV=coefficient of variation

The findings indicate the effectiveness of improved cultivation technologies in managing pests and diseases, reducing whitefly, leaf miner, aphid, tomato mosaic disease, and tomato bacteria leaf blight. Abbas *et al*. [20] supported chemical pesticides' efficacy, attributing it to Glutathione s-transferase inhibition. Organic treatments also showed promise, aligning with Fening *et al*. [21], who highlighted neem extract's potential in crop protection. Although inorganic treatments were as effective as Organic 1, the latter is environmentally friendly, making it a preferred option.

3.5. Effects of Variety and Cultivation Technology on Number of Trusses, Flower and Fruit Yield

Findings revealed significant effects of management practices on the incidence and severity of bacteria leaf blight in tomatoes over the two-year evaluation (Table 8). For the incidence of late blight disease, treatments significantly affected it during both years ($P \leq 0.05$), with significant interactions in 2023. The improved variety consistently showed lower incidence at 2 WAT (14.0 and 24.0%) and 4 WAT (5.2 and 16.5%) compared to the local variety. Inorganic treatments resulted in lower mean incidence at 2 (10.0 and 10.3%) and 4 WAT (0.0%) in 2022 and at 2 (20.0%) and 4 WAT (10.7 and 10.3%) in 2023. Control plots consistently had the highest mean incidence for both varieties in both years. Regarding the severity of late blight disease, treatments significantly influenced it during both years ($P \leq 0.05$), with no significant interactions. The improved variety consistently showed lower severity at 2 WAT (2.5 and 2.4) and 4 WAT (1.6 and 18.0) compared to the local variety. Inorganic treatments resulted in lower mean severity at 2 (2.0) and 4 WAT (1.0) in 2022 and at 2 (2.0) and 4 WAT (1.0) in 2023. Control plots consistently exhibited the highest mean severity in 2022. Overall, severity was higher in 2022 than in 2023.

Table 8. *Effects of variety and cultivation technology on the incidence and severity of tomato bacteria leaf blight disease.*

Treatment	2022				2023			
	Bacteria leaf blight incidence		Bacteria leaf blight severity		Bacteria leaf blight incidence		Bacteria leaf blight severity	
	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP	2 WAP	4 WAP
Variety								
Improved (Heirloom)	14.0±1.3[a]	5.2±0.4[a]	2.5±0.2[a]	1.6±0.1[a]	24.0±1.5[a]	16.5±1.3[a]	2.4±1.0[a]	1.8±0.6[a]
Local (Nornro)	14.8±1.3[a]	5.3±0.4[a]	2.6±0.2[a]	1.6±0.1[a]	25.0±1.6[a]	17.7±1.2[a]	2.4±1.0[a]	1.8±1.5[a]
CT 1 Heirloom	10.5±1.0[c]	5.1±0.6[b]	2.5±0.3[b]	1.0±0.0[b]	20.6±0[c]	10.0±0[e]	2.3±0.0[b]	1.0±0.0[b]
CT 1 Nornro	13.3±1.3[b]	5.2±0.5[b]	2.5±0.3[b]	1.0±0.0[b]	23.3±3.3[b]	13.3±3.3[d]	2.3±0.0[b]	1.0±0.0[b]
CT 2 Heirloom	15.0±1.9[ab]	5.5±0.5[b]	2.6±0.4[b]	1.0±0.0[b]	25.0±2.9[ab]	15.0±2.9[c]	2.7±0.3[a]	1.0±0.0[b]
CT 2 Nornro	15.7±1.3[ab]	5.7±0.3[b]	2.3±0.3[b]	1.0±0.0[b]	26.7±3.3[ab]	16.7±3.3[c]	2.3±0.3[a]	1.0±0.0[b]
CT 3 Heirloom	10.0±1.3[c]	0.0±0.0[c]	2.0±0.0[b]	1.0±0.0[b]	20.0±3.3[c]	10.7±3.3[c]	2.0±0.3[a]	1.0±0.0[b]
CT 3 Nornro	10.3±1.3[c]	0.0±0.0[c]	2.0±0.0[b]	1.0±0.0[b]	20.0±3.3[c]	10.3±3.3[b]	2.0±0.3[a]	1.0±0.0[b]
CT 4 Control Heirloom	20.7±2.3[a]	10.7±3.3[a]	3.3±0.0[a]	3.5±0.6[a]	30.7±3.3[a]	30.6±3.3[a]	3.0±0.0[a]	3.0±0.0[a]
CT 4 Control Nornro	20.0±2.0[a]	10.0±0.0[a]	3.3±0.0[a]	3.5±0.8[a]	30.0±0.0[a]	30.5±0.0[a]	3.0±0.0[a]	3.0±0.2[a]
F-Statistic								
Treatment (Pr> F)	<0.001	<0.001	0.05	<.001	<.001	<.001	0.040	<.001
Variety (Pr> F)	ns	ns	ns	ns	0.05	0.05	ns	ns
Treatment × variety (Pr> F)	ns	ns	ns	ns	0.05	0.05	ns	ns
Treatment × Year (Pr> F)	ns	ns	ns	ns	0.05	0.05	ns	ns
CV (%)	14.7	12.0	14.0	10.0	14.6	11.0	9.0	8.6

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; ns = non-significant at 5% SNK; CT=cultivation technology; CV=coefficient of variation

The statistical analysis of variance indicated significant effects of both variety and treatment factors ($P \leq 0.05$) on the number of trusses and flowers in tomato plants, with significant interactions between variety and treatment observed in both 2022 and 2023 (Table 9). The local variety consistently outperformed the improved variety, exhibiting higher numbers of trusses (13.4 and 13.6 plant^{-1}) and flowers (38.1 and 38.6 plant^{-1}) in the 2022 and 2023 cropping seasons, respectively. The CT 1 plot recorded the highest numbers of trusses (24.00 and 22.33 plant^{-1}) and flowers (57.13 and 55.66 plant^{-1}) for both local and improved varieties across the two years.

***Table 9**. Effects of variety and cultivation technology on number of trusses per plant and number of flowers per plant.*

Treatment	2022		2023	
	Number of trusses plant^{-1}	Number of flowers plant^{-1}	Number of trusses plant^{-1}	Number of flowers plant^{-1}
Variety				
Improved (Heirloom)	12.4	36.1	12.5	36.7
Local (Nornro)	13.4	38.1	13.6	38.7
CT 1 Heirloom	22.9±1.0^{a}	55.0±5.2^{ab}	20.0±0.6^{a}	53.3±4.4^{a}
CT 1 Nornro	24.0±2.4^{a}	57.1±5.1^{a}	22.3±1.5^{a}	55.7±8.7^{a}
CT 2 Heirloom	14.0±1.7^{b}	44.7±4.0^{b}	13.7±1.2^{b}	41.3±3.7^{b}
CT 2 Nornro	15.8±1.7^{b}	44.1±6.4^{b}	15.0±1.5^{b}	43.0±7.0^{b}
CT 3 Heirloom	7.6±1.4^{c}	25.0±2.0^{d}	9.3±1.2^{c}	29.3±2.3^{d}
CT 3 Nornro	8.0±1.0^{c}	30.1±1.8^{c}	10.0±1.2^{c}	33.0±1.5^{c}
CT 4 Control Heirloom	5.1±1.0.8^{d}	20.0±1.8^{e}	7.3±1.3^{d}	24.0±0.6^{e}
CT 4 Control Nornro	6.0±0.5^{d}	21.2±1.8^{e}	7.0±0.0^{d}	23.0±1.7^{e}
F-Statistic				
Treatment (Pr> F)	<0.001	<0.001	<0.001	<0.001
Variety(Pr> F)	0.05	0.05	0.05	0.05
Treatment × Variety	0.02	0.04	0.02	0.05
CV (%)	15.6	13.0	10.0	13.7

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; ns = non-significant at 5% SNK; CT= cultivation technology; CV=coefficient of variation

***Table 10**. Effects of variety and cultivation technology on fresh fruit yield of tomato.*

Treatment	2022	2023
	Fresh fruit yield (t ha^{-1})	Fresh fruit yield (t ha^{-1})
Variety		
Improved (Heirloom)	2.8±0.2b	3.1±0.3^{a}
Local (Nornro)	3.5±0.2a	3.4±0.3^{a}
CT 1 Heirloom	4.2±0.3^{b}	4.6±0.3^{b}
CT 1 Nornro	5.3±0.5^{a}	5.5±0.5^{a}
CT 2 Heirloom	4.5±0.4^{b}	4.5±0.2^{b}
CT 2 Nornro	5.6±0.5^{a}	4.6±0.4^{b}
CT 3 Heirloom	2.0±0.1^{c}	2.6±0.1^{c}
CT 3 Nornro	2.5±0.2^{c}	2.7±0.2^{c}
CT 4 Control Heirloom	0.5±0.0^{d}	0.5±0.0^{d}
CT 4 Control Nornro	0.6±0.0^{d}	0.6±0.0^{d}
F-Statistic		

Treatment	2022 Fresh fruit yield (t ha^{-1})	2023 Fresh fruit yield (t ha^{-1})
Treatment (Pr> F)	<.001	<.001
Variety (Pr> F)	0.050	ns
Treatment × variety (Pr> F)	0.050	ns
Treatment × year(Pr> F)	ns	ns
CV (%)	10.0	13.0

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; ns = non-significant at 5% SNK; CT=cultivation technology; CV=coefficient of variation

Variety and biotic constraint management options significantly (P<0.05) influenced fresh fruit yield during both 2022 and 2023 (Table 10). Local variety consistently produced higher fresh fruit yields of 5.6 and 4.6, and 3.5 and 3.4 t ha^{-1}, compared to the improved variety (2.8 t ha^{-1} and 3.1 t ha^{-1}) in both years, respectively. The CT 1 treated plots showed the highest fruit yield for both improved (4.2 t ha^{-1} and 4.6 t ha^{-1}) and local (5.3 t ha^{-1} and 5.5 t ha^{-1}) varieties in 2022 and 2023, respectively. Overall, the fresh fruit yields for both varieties were slightly higher in 2023 than in 2022. Control plots consistently recorded the lowest fresh fruit yields for both improved and local varieties across both evaluation years. These findings emphasize the significance of both variety selection and specific treatments, particularly CT 1, in influencing the growth, flowering, and fresh fruit yield of tomato. Findings also indicate that organic amendments not only improve soil conditions, but also soil-water-plant relations, by modifying soil bulk density, total porosity, and importantly provide nutrients. Consequently, amendments increase plant growth, yield and water use efficiency [22]. In addition, several reports mentioned that application of different organic soil amendments can increase the yield of crops including lettuce [23], potato [24], and tomato [25]. The observed interactions between variety and treatment further highlight the need for a holistic approach in optimizing tomato crop production.

3.6. Effects of Variety and Cultivation Technology of Tomato on Weed Density (Weeds m^{-2}) and Weed Dry Weight (g m^{-2})

The study investigated the impact of treatments on the yield of tomato crops and weed management over two evaluation years. The results showed significant effects of treatments ($P \leq 0.05$) on fruit and seed yield, with significant interactions between variety × treatment, and treatment × year factors (Table 12). Weed infestation was influenced by the treatments, with a significant reduction observed in inorganic treated plots, where permethrin herbicide was applied. Generally, the quantity of weeds in the experimental field was higher in 2023 than in 2022. In 2022, at 2 and 4 WAT, the weed quantity was notably lower in CT 3 treated plots (2.66 and 6.03 weeds m^{-2}) compared to CT 2 (3.46 and 6.36 weeds m^{-2}) and control (20.66 and 60.60 weeds m^{-2}) plots. A similar trend was observed in 2023, with CT 3 plots showing lower weed quantities at 2 and 4 WAT (4.06 and 7.33 weeds m^{-2}) compared to other treatments.

***Table 11.** Effects of variety and cultivation technology on weed density.*

Treatment	Weed density (weeds m^{-2})			
	2022		2023	
	2 WAP	4 WAP	2 WAP	4 WAP
Variety				
Improved (Heirloom)	8.7 ±0.80^{a}	22.1 ±2.00^{a}	11.4 ±0.10^{a}	24.1 ±2.00^{a}
Local (Nornro)	9.0 ±0.70^{a}	22.0 ±2.00^{a}	11.3 ±0.10^{a}	25.6 ±2.11^{a}
CT 1 Heirloom	8.60 ±0.10^{b}	15.30 ±1.60^{b}	10.60 ±0.20^{b}	18.33 ±1.66^{b}
CT 1 Nornro	7.67 ±0.13^{b}	15.34 ±1.07^{b}	9.67 ±0.33^{b}	18.33 ±1.67^{b}

Treatment	Weed density (weeds m^{-2})			
	2022		2023	
	2 WAP	4 WAP	2 WAP	4 WAP
CT 2 Heirloom	3.46±0.03^{c}	6.36±0.06^{c}	5.40±0.13^{c}	9.33±0.66^{c}
CT 2 Nornro	3.13±0.06^{c}	6.03±0.60^{c}	5.10±0.06^{c}	9.33±0.67^{c}
CT 3 Heirloom	2.66±0.16^{c}	6.03±0.06^{c}	4.06±0.16^{d}	7.33±0.66^{c}
CT 3 Nornro	2.33±0.03^{c}	6.60±1.03^{c}	4.30±0.33^{d}	8.66±1.33^{c}
CT 4 Control Heirloom	20.66±0.60^{a}	60.60±1.60^{a}	25.66±0.66^{a}	61.67±1.66^{ab}
CT 4 Control Nornro	23.00±0.70^{a}	60.33±1.30^{a}	26.00±0.00^{a}	66.03±1.33^{a}
F-Statistic				
Treatment(Pr> F)	<.0001	<.0001	<.0001	<.0001
Variety(Pr> F)	ns	Ns	ns	ns
Treatment ×variety(Pr> F)	ns	Ns	ns	ns
Treatment ×Year(Pr> F)	ns	Ns	ns	ns
CV (%)	12.9	10.3	10.0	20.3

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; ns = non-significant at 5% SNK; CT=cultivation technology; CV=coefficient of variation

Table 12. *Effects of variety and cultivation technology on weed dry matter.*

Treatment	Weed dry weight (g m^{-2})			
	2022		2023	
	2 WAP	4 WAP	2 WAP	4 WAP
Variety				
Improved (Heirloom)	6.7±0.53a	8.4±0.60a	4.9±0.23a	6.8±0.63a
Local (Nornro)	6.8±0.46a	8.6±0.16a	5.0±0.16a	6.9±0.65a
CT 1 Heirloom	6.96±0.13b	8.00±0.10b	4.96±0.23b	6.40±0.20b
CT 1 Nornro	6.83±0.16b	8.20±0.10b	4.83±0.16b	6.23±0.13b
CT 2 Heirloom	4.33±0.10c	5.33±0.06c	2.33±0.16c	3.33±0.16c
CT 2 Nornro	4.33±0.10c	5.30±0.06c	2.33±0.16c	3.33±0.16c
CT 3 Heirloom	2.06±0.03d	3.60±0.30d	1.06±0.03d	1.96±0.03d
CT 3 Nornro	2.93±0.00d	3.07±0.30d	0.93±0.06d	1.97±0.03d
CT 4 Control Heirloom	13.66±0.63a	17.07±0.33a	11.66±0.33a	15.67±0.33a
CT 4 Control Nornro	13.00±0.80a	18.03±0.60a	12.00±0.50a	16.33±0.67a
F-Statistic				
Treatment (Pr> F)	<.001	<.001	<.001	<.001
Variety (Pr> F)	ns	ns	ns	ns

Treatment	Weed dry weight (g m^{-2})			
	2022		2023	
	2 WAP	4 WAP	2 WAP	4 WAP
Treatment × variety (Pr> F)	ns	ns	ns	ns
Treatment × Year (Pr> F)	ns	ns	ns	ns
CV (%)	8.5	16.0	10.2	10.0

Means with the same superscripts in column are not significantly different (P>0.05) as indicated by Student Newman-Keuls multiple range test; ns=non-significant at 5% SNK; CT=cultivation technology; CV=coefficient of variation.

Weed dry weight was significantly influenced by treatments in both years (Table 12). In 2022, inorganic treated plots had the lowest weed dry weight at 2 and 4 WAT (2.06 and 3.60 g m^{-2}), followed by organic 2 treated plots (4.33 and 5.33 g m^{-2}), and control plots had the highest (13.66 and 17.07 g m^{-2}). A similar pattern was observed in 2023, with lower weed dry weights in inorganic treated plots at 2 and 4 WAT (1.06 and 1.96 g m^{-2}). The study emphasizes the significance of treatments in managing weed infestation, with inorganic treatments showing more effective weed control compared to organic treatments and control plots. The observed interactions highlight the complexity of the relationships between varietal selection, treatment application, and environmental conditions in determining crop yield and weed management outcomes. Findings indicate that some amendment species have toxic effects on the growth of tomato plants. This agrees with the view that some amendment species have toxic effects on the growth of some plants, such as the green manure of Brassicaceae plants (*Brassica juncea* L., *Sinapsis alba* L.) [26], sunflower (*Helianthus annus* L.), dhaincha (*Sesbania aculeata* Poiret) [27], or red clover (*Trifolium pratense* L.) [28]. Weed control is essential for optimal crop yields as depicted in the improved agronomic management practices compared to the control, which was consistent with Tiwari *et al*. [29], who emphasized weeding efficacy for improved growth and yield of crop.

4. Conclusions

This study assessed organic and inorganic methods for improving tomato growth and managing pests, diseases, and weeds. Findings demonstrate that variety and cultivation technology (crop management practices) boost tomato tolerance to pests and diseases, as well as its growth and yield that could be exploited for increased production and fruit quality of the crop. Cultivation technology 1 (CT 1), comprising chicken dung and *Gliricidia sepium* mulching, was the most effective, followed by CT 2, while CT 4 could not support the crop partly due to poor soil structure and fertility status. The outperformance of the organic treatments relative to the inorganic and control is suggested to be attributable to its nitrogen-rich components. Moreover, agronomic management practices involving organic materials applied at optimal rates are environmental friendly. Weed control was also established to be effective in both inorganic and CT 2 treatments. The findings suggest that the CT 1 should be promoted for sustainable tomato cultivation, prioritizing environmentally friendly methods for long-term success.

Abbreviations

CARI	Central Agricultural Research Institute
CT	Cultivation Technology
RCBD	Randomized Complete Block Design
SLARI	Sierra Leone Agricultural Research Institute
WAT	Weeks After Transplanting

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Conflicts of Interest

The authors declare no conflicts of interest.

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