

Book Chapter: Varietal and Management-Based Modulation of Pests, Diseases, Weeds, and Yield Traits in Tomato Production and Productivity

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Abstract

Tomato (*Solanum lycopersicum* L.) plays a vital nutritional and economic role in Sierra Leone; however, its production is hindered by pest infestations, disease outbreaks, weed competition, and suboptimal agronomic practices. This study assessed the impact of two tomato varieties which are Heirloom (improved) and Nornro (local) under four agronomic management practices (AMPs), combining organic and inorganic approaches, over a two-year field trial (2022-2023) at Njala University. The experiment followed a 2 × 4 factorial design in a Randomized Complete Block Design (RCBD) with three replications. AMP 1, which included chicken manure, mulching, and neem biopesticide, significantly improved plant height, branch number, truss formation, and fruit yield (up to 5.3 t/ha), outperforming both the inorganic treatment (AMP 3: 4.6 t/ha) and the control (AMP 4: 2.5 t/ha). AMP 3, involving NPK fertilizer and chemical pesticides, was most potent in reducing pest populations (whiteflies, aphids, and leaf miners), disease incidence (tomato mosaic and bacterial leaf blight), and weed infestation. Conversely, AMP 1 also effectively enhanced soil health and economic returns, producing the highest net revenue (SLL 380,000/ha). The local Nornro variety demonstrated superior pest and disease resistance, while the Heirloom variety exhibited better vegetative growth. Weed surveys revealed diverse species dominated by Poaceae and Fabaceae families, with *Imperata cylindrica* and *Panicum maximum* being most prevalent. Overall, integrated organic and inorganic practices significantly influenced tomato productivity, weed suppression, and profitability. The findings advocate for

the adoption of AMP 1 as a sustainable and eco-friendly strategy for enhanced tomato cultivation in low-input agricultural systems in Sierra Leone.

Keywords

Pests, Diseases, Management, Agronomic practices, Tomato Production and Productivity

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 [3].

Organic manures present a viable alternative, being more accessible and cost-effective compared to chemical fertilizers [4]. 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 [5]. 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 [6]. Poultry manure enhances soil nutrient content and structure, while mustard oil cake shows potential in improving yields of grafted tomatoes [7]. 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 [8] [9].

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

[10]. 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 [11], devil weed [12], cabbage waste [13], chicken dung [14], sunflower [15] and carbonized rice hull [16].

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 aimed at evaluating the performance of two tomato varieties under different agronomic management strategies for their response to insects, weeds, diseases, growth, yield and productivity of tomatoes.

2. Materials and Method

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 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 °C to 23 °C 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.

2.2. Experimental Material, 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 agronomic management practices including agronomic management practice 1 (AMP 1), agronomic management practice 2 (AMP 2), agronomic management

practice 3 (AMP 3) and control. AMP 1 involved the use of chicken manure (CM) at 5 t ha⁻¹, mulching at 7kg/plot and neem biopesticide. After incorporation CM, the manure was left to decompose for two weeks before transplanting. Mulching (*Gliricidia sepium*) was applied one week after transplanting to prevent pest and weeds emerging. 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 H₂O⁻¹, left to ferment for about a week and then applied. The AMP 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 H₂O⁻¹ ha⁻¹. The AMP 3 comprised the application of pre-emergence herbicide promithrine at 6 ml 6 L H₂O⁻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 H₂O⁻¹ ha⁻¹ when pests attacked and copper hydroxide at 12.012 g 6 L H₂O⁻¹ ha⁻¹ when diseases attacked the plants). The APM 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 arrangements implemented in a Randomized Complete Block Design (RCBD) with three replications. The plot size was 3 m × 5.25 m (15.75 m²). 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.

$$\text{Number of fruits per plant} = \frac{\text{Total number of fruits from ten hills}}{10}$$

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.

$$\text{Fresh fruits weight per plant} = \frac{\text{Total number of fresh fruits from ten hills}}{10}$$

The insect pest population was determined 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.

$$\text{Number of insects per plant} = \frac{\text{Total number of insects on ten plants}}{10}$$

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.

$$\text{Percent leaf damage per plot} = \frac{\text{Total percent leaf damage by insects on ten plants}}{10} \times 100$$

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.* (2004).

$$\text{Mean incidence (\%)} = \frac{\sum \text{Infected plants}}{\sum \text{plants}} \times 10$$

The severity of diseases was calculated from ten randomly selected plants using a scale 1 - 5 as provided by Sseruwagi *et al.* (2004).

The weed populations in the field were evaluated at 3 and 5 WAT. A quadrat measuring 0.5 m² 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 °C for 48 h before reweighing, until a constant weight was obtained. This process ensured accurate measurements of the weed biomass.

2.4. Economic Analysis

The economic analysis was determined using partial budgeting (Okoruwa *et al.* 2005) to compare cost-effectiveness of the various weed control treatments in maize production systems. Thus, the gross margin was computed as follows:

The unit price of 1 kg of cucumber was obtained from the open market to determine the total revenue (TR).

$$\text{Total revenue (TR)} = \text{Maize yield (t ha}^{-1}\text{)} \times \text{Unit price of maize (SLL t ha}^{-1}\text{)}.$$

$$\text{Gross margin (SLL ha}^{-1}\text{)} = \text{Total revenue (SLL ha}^{-1}\text{)} - \text{Variable cost (SLL ha}^{-1}\text{)}$$

Variable costs (VC) are expenditures on Land preparation, planting material, cost of planting, cost of herbicide application, cost of herbicides, cost of *Gliricidia sepium* application, labour cost of acquiring *Gliricidia sepium*, weeding, biofertilizer, processing neem, and cost of manufactured neem extract.

2.5. Data Analysis

Data was subjected to analysis of variance (ANOVA) using the GENSTAT statistical programme (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 $\alpha = 0.05$. 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. Physico-Chemical Properties of Soil

Soil analysis conducted across the 2022 and 2023 cropping seasons in **Table 1** revealed that the soil was initially highly acidic, with pH values ranging from 3.7 to 6.2, accompanied by low nitrogen and potassium levels and moderate phosphorus levels. These conditions indicated a soil environment that was not only nutrient-deficient but also severely constrained by high acidity. The persistently low pH, despite minor improvements in nutrient levels post-harvest, suggests that inorganic fertilizers were applied without sufficient organic amendments or liming in the initial stages. This has likely contributed to further acidification and restricted nutrient availability, particularly phosphorus, due to fixation by aluminum and iron in strongly acidic soils. However, following the application of soil amendments such as organic materials agents a noticeable increase in soil pH was recorded. This pH elevation reflects a positive shift in soil reaction toward less acidic conditions, enhancing nutrient bioavailability and reducing aluminum toxicity. The gradual rise in nitrogen levels after harvest in both seasons further indicates the combined influence of inorganic nitrogen fertilizers and mineralization of added organic matter. Despite this improvement, nitrogen levels remained suboptimal, suggesting either insufficient organic inputs or continued leaching under the still acidic, albeit improved, conditions. Moderate phosphorus levels, likely resulting from inorganic phosphorus fertilizer application, continued to face reduced effectiveness due to residual soil acidity, although improved pH conditions may have slightly mitigated phosphorus fixation. Potassium levels fluctuated, implying some level of supplementation, but were not sustained likely due to leaching and plant uptake in low cation exchange capacity (CEC) soils.

Table 1. Physico-chemical properties of soil sample of the experimental site for 2022 and 2023 cropping season.

Properties	Sampling in 2022 before planting	Sampling in 2022 after harvesting	Sampling in 2023 before planting	Sampling in 2023 after planting
Soil pH (1:1 H ₂ O)	3.9	6.2	3.7	6.0
Soil pH (1:1 KCl)	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

3.2. Effect of Variety and Agronomic Management Practice on Growth of Tomato

Variety, agronomic management treatment, and variety \times treatment interactions significantly ($P \leq 0.05$) influenced growth (plant height and number of branches) of tomato plants (**Table 2**). For plant height, the Heirloom variety consistently exhibited the highest measurements at 3 and 5 weeks after transplanting (WAT)

in both years. In 2022, the Heirloom variety reached 29.2 cm and 39.6 cm, while in 2023, the plants were 27.2 cm and 42.8 cm tall at 3 and 5 WAT, respectively. In contrast, the Nornro variety produced shorter plants at 3 WAT (22.6 cm and 24.8 cm) and 5 WAT (37.8 cm and 40.0 cm) for both years, respectively. The AMP 1 treated plots consistently recorded tallest plants at 3 WAT (30.33 cm and 38.43 cm) and 5 WAT (50.53 cm and 54.33 cm) in 2022 and 2023, respectively. Similarly, the APM 1 treated plot recorded the highest number of branches at different sampling regimes followed by AMP 3. Overall, treated plots, especially those with AMP 1, produced significantly taller plants and higher numbers of branches compared to AMP 4 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.

Table 2. Growth response of tomato under organic and inorganic control condition for 2023 cropping season.

Treatment	2022				2023			
	Plant height (cm)		Number of branches plant ⁻¹		Plant height (cm)		Number of branches plant ⁻¹	
	3WAT	5WAT	3 WAT	5WAT	3WAT	5WAT	3WAT	5WAT
Variety								
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
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
AMP 1	30.3 ± 2.3 ^a	50.5 ± 2.2 ^a	0.0 ± 0.0 ^c	1.8 ± 0.1 ^c	38.4 ± 2.0 ^a	54.3 ± 3.6 ^a	0.0 ± 0.0 ^c	1.3 ± 0.3 ^d
AMP 2	20.9 ± 1.3 ^b	33.7 ± 1.5 ^b	0.0 ± 0.0 ^c	1.4 ± 0.4 ^c	24.9 ± 1.9 ^{ab}	39.7 ± 2.4 ^{ab}	0.0 ± 0.0 ^c	1.0 ± 0.0 ^d
AMP 3	25.2 ± 1.6 ^c	46.1 ± 2.0 ^c	0.0 ± 0.0 ^c	1.6 ± 0.9 ^c	30.2 ± 2.4 ^c	48.0 ± 2.4 ^c	0.0 ± 1.0 ^c	1.0 ± 0.0 ^d
AMP 4	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 ± 2.0 ^c	0.0 ± 0.0 ^c	0.0 ± 0.0 ^e
F-Statistic								
Treatment (Pr > F)	0.020	0.05	0.047	<0.001	<0.001	<0.001	<0.001	<0.001
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; AMP = agronomic management practices; CV = coefficient of variation.

3.3. Effects of Variety and Agronomic Management Practice on Number and Percentage Damage of 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 3 and 5 weeks after transplanting (Table 3 and Table 4). Across both years, the local variety consistently exhibited lower whitefly counts at 3 weeks after transplanting (WAT) (7.8 and 8.0 plant⁻¹) and at 5 WAT (2.7 and 4.5 plant⁻¹) regardless of treatment, compared to the improved variety at 3 WAT (8.6 and 8.1 plant⁻¹) and at WAT (2.9 and 4.6 plant⁻¹). In 2022 and 2023, inorganic treatment plots (AMP 3) consistently recorded the lowest whitefly counts at 3 WAT (4.00 and 4.09 plant⁻¹) and at 5 WAT (0.00 and 0.00 plant⁻¹). The AMP 1 treated plot showed higher whitefly counts compared to AMP 3 but were lower than AMP 4. Notably, whitefly populations were lower in 2022 across all evaluation periods compared to 2023.

Table 3. Effects of organic and inorganic management on the population and percentage damage of whitefly in 2022 and 2023 cropping seasons.

Treatment	2022				2023			
	Number of whiteflies plant ⁻¹		Percentage damage of whiteflies (%)		Number of whiteflies plant ⁻¹		Percentage damage of whiteflies (%)	
	3WAT	5WAT	3 WAT	5WAT	3WAT	5WAT	3WAT	5WAT
Variety								
Heirloom	8.6 ± 0.5 ^a	2.9 ± 0.0 ^a	35.0 ± 0.0 ^a	20.5 ± 0.0 ^a	8.1 ± 0.6 ^a	4.6 ± 0.2 ^a	40.5 ± 0.3 ^a	25.3 ± 0.4 ^a
(Nornro)	7.8 ± 0.4 ^a	2.7 ± 0.0 ^a	34.0 ± 0.0 ^a	20.0 ± 0.0 ^a	8.0 ± 0.5 ^a	4.5 ± 0.2 ^a	40.4 ± 0.5 ^a	25.2 ± 0.4 ^a
AMP 1	7.5 ± 1.5 ^b	2.0 ± 0.5 ^b	25.6 ± 0.0 ^b	10.0 ± 0.0 ^b	8.0 ± 0.5 ^b	3.0 ± 0.5 ^b	35.0 ± 2.0 ^b	25.3 ± 3.3 ^b
AMP 2	8.2 ± 1.6 ^b	2.6 ± 0.7 ^b	25.4 ± 0.6 ^b	15.0 ± 0.0 ^b	9.1 ± 0.7 ^b	3.7 ± 0.6 ^b	40.7 ± 2.0 ^b	30.0 ± 1.7 ^b
AMP 3	4.0 ± 1.3 ^c	0.0 ± 0.0 ^c	25.0 ± 1.6 ^b	5.0 ± 0.0 ^b	4.6 ± 0.3 ^c	0.0 ± 0.0 ^c	25.4 ± 1.6 ^c	10.0 ± 0.0 ^c
AMP 4	10.5 ± 1.6 ^a	7.0 ± 0.7 ^a	50.0 ± 0.3 ^a	10.0 ± 1.5 ^a	11.0 ± 1.6 ^a	12.7 ± 1.3 ^a	55.0 ± 2.0 ^b	55.5 ± 1.9 ^a
F-Statistic								
Treatment (Pr > F)	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	0.044	<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
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.

Similarly, agronomic management practices significantly influenced the percentage damage caused by whiteflies over the two evaluation years, with no significant Varietal or Variety × Treatment interactions at 3 and 5 weeks after transplanting. The local variety consistently exhibited lower percentage damage at both 3 WAT (34.0 and 40.4%) and 5 WAT (20.0 and 25.2%) compared to the improved variety.

AMP 3 consistently resulted in the lowest percentage leaf damage for both varieties, followed by APM 1 treatment. AMP 4 or 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.

Table 4. Effects of variety and agronomic management practice on the population and percentage damage of leaf miner in 2022 and 2023 cropping seasons.

Treatment	2022				2023			
	Number of leaf miner plant ⁻¹		Percentage damage of leaf miner (%)		Number of leaf miner plant ⁻¹		Percentage damage of leaf miner (%)	
	3WAT	5WAT	3 WAT	5WAT	3WAT	5WAT	3WAT	5WAT
Variety								
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	15.3 ± 0.5 ^a
Nornro	4.9 ± 0.0 ^a	2.7 ± 0.0 ^a	20.5 ± 1.6 ^a	11.3 ± 0.7 ^a	5.8 ± 0.5 ^a	2.7 ± 0.0 ^a	24.1 ± 1.2 ^a	15.5 ± 0.6 ^a
AMP 1	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
AMP 2	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	15.0 ± 2.9 ^b
AMP 3	2.7 ± 0.6 ^c	0.0 ± 0.0 ^c	15.0 ± 0.0 ^c	5.0 ± 0.0 ^c	4.7 ± 0.6 ^b	0.7 ± 0.0 ^c	20.0 ± 0.0 ^d	5.5 ± 0.0 ^c
AMP 4	7.0 ± 0.0 ^a	6.0 ± 0.0 ^a	30.3 ± 3.0 ^a	36.5 ± 3.0 ^a	7.2 ± 0.0 ^a	6.0 ± 0.0 ^a	38.3 ± 6.0 ^a	35.3 ± 6.0 ^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.

The Heirloom variety in **Table 5** and **Table 6** consistently exhibited in lower leaf miner counts at 3 WAT (4.8 and 5.6 plant⁻¹) and at 5 WAT (2.6 and 2.7 plant⁻¹) compared to the local variety. AMP 3 plots consistently showed the lowest leaf miner counts at 3 WAT (2.7 and 4.7 plant⁻¹) and 5 WAT (0.5 and 0.8 plant⁻¹), followed by APM 1 treated plot for both 2022 and 2023 evaluation years. However, AMP 4 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 Heirloom variety consistently demonstrated a lower percentage of leaf damage at both 3WAT (20.0 and 23.6%) and 5WAT (11.2 and 11.3%) compared to the local variety. AMP 3 treated plots resulted in the lowest percentage leaf damage at 3WAT (15.5 and 20.0 %) and 5WAT (5.0 and 5.5%), followed by AMP 1 treated plots, while AMP 4 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 the aphid population, the local variety consistently had lower leaf aphid counts at 3 WAT (3.8 and 4.3 plant⁻¹) and at 5WAT (2.3 and 1.9 plant⁻¹) compared to the improved variety (Table 5). AMP 3 treated plots had the lowest leaf aphid counts at 3 (2.7 and 2.1 plant⁻¹) and 5WAT (0.7 and 0.6 plant⁻¹) for both 2022 and 2023 cropping year, followed by APM 1 treated plots, across both years. However, AMP 4 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).

Table 5. Effects of variety and agronomic management practice on the incidence and severity of tomato mosaic disease.

Treatment	2022				2023			
	Incidence		Severity		Incidence		Severity	
	3WAT	5WAT	3WAT	5WAP	3WAT	5WAT	3WAT	5WAT
Variety								
Heirloom	21.3 ± 0.1 ^a	16.5 ± 1.0 ^a	2.8 ± 0.1 ^a	1.8 ± 0.1 ^a	22.5 ± 1.1 ^a	16.5 ± 0.6 ^a	2.7 ± 0.1 ^a	2.1 ± 0.2 ^a
Nornro	20.8 ± 0.1 ^a	16.4 ± 1.0 ^a	2.7 ± 0.2 ^a	1.8 ± 0.1 ^a	20.2 ± 1.2 ^a	16.4 ± 0.6 ^a	2.7 ± 0.1 ^a	2.0 ± 0.0 ^a
AMP 1	22.0 ± 0.0 ^b	10.0 ± 0.0 ^b	2.5 ± 0.0 ^b	1.0 ± 0.1 ^b	20.0 ± 0.0 ^b	10.0 ± 0.0 ^b	2.5 ± 0.0 ^b	1.5 ± 0.1 ^b
AMP 2	22.0 ± 2.9 ^b	10.0 ± 2.9 ^b	2.7 ± 0.3 ^b	1.0 ± 0.3 ^b	20.0 ± 2.9 ^b	10.0 ± 2.9 ^b	2.4 ± 0.3 ^b	1.7 ± 0.3 ^b
AMP 3	10.7 ± 1.3 ^c	5.7 ± 3.3 ^c	2.1 ± 0.3 ^b	1.6 ± 0.3 ^b	10.6 ± 1.3 ^c	5.5 ± 3.3 ^c	2.0 ± 0.3 ^b	1.2 ± 0.3 ^b
AMP 4	30.7 ± 1.3 ^a	40.0 ± 3.3 ^a	4.0 ± 0.0 ^a	4.3 ± 0.0 ^a	39.7 ± 1.3 ^a	40.0 ± 3.3 ^a	4.0 ± 0.0 ^a	4.0 ± 0.0 ^a
F-Statistic								
Treatment (Pr > F)	<0.001	<0.001	0.05	<0.001	<0.001	<0.001	<0.001	<0.001
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; AMP = agronomic management practice; CV = coefficient of variation.

Table 6. Effects of variety and agronomic management practice on the population and percentage damage of leaf aphid in 2022 and 2023 cropping seasons.

Treatment	2022				2023			
	Number of aphid plant ⁻¹		Percentage damage of aphid (%)		Number of aphid plant ⁻¹		Percentage damage of aphid (%)	
	3WAT	5WAT	3WAT	5WAT	3WAT	5WAT	3WAT	5WAT
Variety								
Heirloom	4.0 ± 0.1 ^a	2.4 ± 0.2 ^a	18.4 ± 0.4 ^a	10.0 ± 0.0 ^a	4.3 ± 0.3 ^a	2.2 ± 0.1 ^a	15.9 ± 1.8 ^a	17.1 ± 0.3 ^a
Nornro	3.8 ± 0.1 ^a	2.3 ± 0.1 ^a	16.9 ± 0.4 ^a	10.0 ± 0.1 ^b	4.3 ± 0.3 ^a	1.9 ± 0.0 ^a	18.2 ± 1.9 ^a	19.2 ± 0.3 ^a
AMP 1	3.0 ± 1.9 ^c	1.0 ± 0.9 ^b	15.1 ± 0.9 ^b	8.6 ± 0.0 ^b	2.3 ± 1.9 ^d	1.3 ± 0.9 ^b	10.2 ± 2.9 ^d	7.6 ± 0.4 ^b
AMP 2	3.6 ± 0.9 ^d	1.6 ± 0.9 ^b	20.0 ± 0.7 ^b	10.0 ± 0.0 ^b	2.7 ± 0.9 ^d	1.7 ± 0.1 ^b	18.7 ± 1.7 ^d	10.7 ± 0.5 ^b
AMP 3	2.7 ± 0.9 ^c	0.7 ± 0.0 ^c	10.5 ± 0.7 ^b	5.0 ± 0.0 ^c	2.1 ± 0.9 ^d	0.6 ± 0.0 ^c	10.0 ± 1.7 ^e	5.0 ± 0.0 ^c
AMP 4	7.3 ± 0.9 ^a	7.3 ± 0.9 ^a	15.0 ± 1.3 ^a	25.3 ± 0.3 ^a	8.3 ± 0.9 ^a	5.3 ± 0.5 ^a	27.3 ± 3.3 ^a	30.3 ± 1.3 ^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	<0.001	ns	ns	ns	ns
Treatment × variety	ns	ns	ns	<0.001	ns	ns	ns	ns
Treatment × year	ns	ns	ns	<0.001	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; AMP = agronomic management practice; CV = coefficient of variation.

Regarding the percentage leaf damage caused by aphids, treatments significantly influenced it during both evaluation years ($P \leq 0.05$), with significant interactions observed at 5 WAT in 2022 ($P \leq 0.05$). The Nornro variety consistently showed lower percentage leaf damage at both 3 WAT (16.9 and 15.2%) and 5 WAT (10.0 and 13.2%) compared to the Heirloom variety. AMP 3 treated plots resulted in the lowest percentage leaf damage at 3WAT (10.5 and 10.0 %) and at 5WAT (5.0 and 5.4 %), 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 agronomic management practices on leaf aphid populations and associated damage, with inorganic treatments showing promising results. Additionally, the Nornro variety displayed greater resistance to leaf aphids compared to the Heirloom variety across both evaluation years.

3.4. Effects of Variety and Agronomic Management Practice of Tomato on Incidence and Severity of Diseases

The study found significant treatment effects on tomato mosaic disease incidence during both evaluation years ($P \leq 0.05$), with significant interactions at 3 WAT in

2023 (Table 7). The Nornro variety had lower incidence at 3WAT (20.8 and 20.2%) and 5WAT (16.4%) compared to the Heirloom variety. AMP 3 showed lower incidence at 3 (10.7 and 10.3%) and 5WAT (5.7 and 5.5%) in both 2022 and 2023 cropping seasons. Overall, disease incidence decreased in 2023 compared to 2022, with AMP 4 plots consistently showing the highest incidence. For disease severity, AMP significantly influenced it during both years ($P \leq 0.05$), though with no significant interactions. The Nornro variety had lower severity at 3WAT (2.7 and 2.4) and 5WAT (1.8 and 1.7) compared to the Heirloom variety. AMP 3 however showed lower severity at 3 (2.0 and 2.1) and 5WAT (1.6 and 1.2) and this was closely followed by AMP 1 in 2022 and 2023 cropping years respectively. AMP 4 plots exhibited the highest severity values. Overall, severity increased in 2023 compared to 2022.

Table 7. Effects of variety and agronomic management practice 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	
	3WAT	5WAT	3WAT	5WAT	3WAT	5WAT	3WAT	5WAT
Variety								
Heirloom	15.0 ± 1.3 ^a	10.0 ± 0.4 ^a	2.5 ± 0.2 ^a	1.6 ± 0.1 ^a	20.0 ± 1.5 ^a	15.0 ± 1.3 ^a	2.4 ± 1.0 ^a	1.8 ± 0.6 ^a
Nornro	17.8 ± 1.3 ^a	13.3 ± 0.4 ^a	2.6 ± 0.2 ^a	1.6 ± 0.1 ^a	23.4 ± 1.6 ^a	17.7 ± 1.2 ^a	2.4 ± 1.0 ^a	1.9 ± 1.5 ^a
AMP 1	14.5 ± 1.0 ^c	10.1 ± 0.6 ^b	2.5 ± 0.3 ^b	1.0 ± 0.0 ^b	20.6 ± 0.0 ^c	10.0 ± 0.0 ^c	2.3 ± 0.0 ^b	1.0 ± 0.0 ^b
AMP 2	20.0 ± 1.9 ^{ab}	15.5 ± 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
AMP 3	10.0 ± 1.3 ^c	5.0 ± 0.0 ^c	2.2 ± 0.0 ^b	1.3 ± 0.0 ^b	20.0 ± 3.3 ^c	10.7 ± 3.3 ^c	2.0 ± 0.3 ^a	1.0 ± 0.0 ^b
AMP 4	25.7 ± 2.3 ^a	27.0 ± 3.3 ^a	3.3 ± 0.0 ^a	3.5 ± 0.6 ^a	30.7 ± 3.3 ^a	35.6 ± 3.3 ^a	3.0 ± 0.0 ^a	3.0 ± 0.0 ^a
F-Statistic								
Treatment (Pr > F)	<0.001	<0.001	0.05	<0.001	<0.001	<0.001	0.040	<0.001
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; AMP = agronomic management practice; CV = coefficient of variation.

Findings also 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, agronomic management practices significantly affected it during both years ($P \leq 0.05$), with significant interac-

tions in 2023. The Heirloom variety showed slightly lower incidence at 3WAT (15.0 and 20.0%) and 5WAT (10.0 and 15.0%) compared to the Nornro variety. AMP 3 resulted in lower mean incidence at 3 (10.0 and 14.7%) and 5 WAT (5.0 and 5.8%) in 2022 and 2023, closely followed by AMP 1. AMP 4 consistently had the highest mean incidence for both varieties in both years. Regarding the severity of late blight disease, crop management practices also significantly influenced it during both years ($P \leq 0.05$), with no significant interactions. The Heirloom variety showed lower severity at 3WAT (2.5 and 2.4) and 4WAT (1.6 and 18.0) compared to the Nornro variety. AMP 3 resulted in lower mean severity at 3 (2.2 and 2.0) and 5 WAT (1.3 and 1.0) in 2022 and 2023. AMP 4 plots exhibited the highest mean severity in both years. 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. Although inorganic treatments were as effective as AMP 1, the latter is environmentally friendly, making it a preferred option.

Table 8. Weed flora composition of the experimental site as influence by cultivation technology in 2022 cropping season.

Family	Species	Method of reproduction	Growth habit	Life cycle	Relative density (%)
Poaceae	<i>Imperata cylindrica</i>	Seeds	Grass	Perenna	56.4
	<i>Panicum maximum</i>	Seeds	Grass	Annual	23.1
	<i>Digitaria ciliaris</i>	Seeds	Grass	Annual	3.4
Fabaceae	<i>Calopogonium mucunoides</i>	Seeds	Broadleaf	perennial	1.1
	<i>Mimosa pudica</i>	Seeds/vegetative	Broadleaf	Annual/perennial	7.8
Rubiaceae	<i>Diodia scandens</i>	Vegetative	Broadleaf	Perennial	2.6
Malvaceae	<i>Sida acuta</i>	seeds	Broadleaf	perennial	1.7
Euphorbiaceae	<i>Croton hirtus</i>	seed	Broadleaf		12.7

3.5. Effects of Variety and Agronomic Management Practice of Tomato on Weed Density (Weeds m⁻²) and Weed Dry Weight (g m⁻²)

The findings documented weed flora along with their families, botanical names growth habit, method of propagation, life cycle and percent relative density (**Table 8**). It was from the findings that experimental site in 2022 cropping year was infested with 8 different weed species which belong to 5 different families when evaluated at 3, 5 and 7 weeks after planting. A similar trend was observed in the experimental site of 2023 where 9 weed species belonging to 6 families were identified at 3, 5 and 7 WAP (**Table 9**). The results revealed that among all the weed species, more than half of the weed species (62.5%) have broadleaf growth habit compared to Grass growth habit (37.5%) in 2022 cropping season. Similarly in the 2023 cropping year, among the growth habits, most of the weed's species (66.6%)

have Broadleaf growth habit compared to those with Grass growth habit (33.4%). The results on the reproductive nature of weed species revealed that, in 2022 cropping year, 87.5% of the weeds reproduce by seeds whilst 12.5% reproduced by vegetative part (Table 8). This was consistent in 2023 where 77.7% of the weed species reproduced by seeds and 22.3% reproduced by vegetative part (Table 9). Among the individual weed species, *Imperata cylindrica*, *Panicum maximum*, and *Croton hirtus* *Euphorbia* were the most dominant species that infested of order in the 2022 cropping year (Table 8) whilst in 2023 cropping year, *Imperata cylindrica*, *Panicum maximum*, and *Mimosa pudica*, were the predominant weeds that significantly infested the cucumber field (Table 9). The findings revealed that in both 2022 and 2023 cropping years, weed species that belong to the families of Poaceae and Fabaceae were the most dominant.

Table 9. Weed flora composition of the experimental site as influence by cultivation technology in 2023 cropping season.

Family	Species	Method of reproduction	Growth habit	Life cycle	Relative density (%)
Poaceae	<i>Imperata cylindrica</i>	Seeds	Grass	Perenna	50.3
	<i>Panicum maximum</i>	Seeds	Grass	Annual	25.9
	<i>Digitaria ciliaris</i>	Seeds	Grass	Annual	2.0
Fabaceae	<i>Calopogonium mucunoides</i>	Seeds	Broadleaf	perennial	1.8
	<i>Mimosa pudica</i>	Seeds/vegetative	Broadleaf	Annual/perennial	9.0
Rubiaceae	<i>Diodia scandens</i>	Vegetative	Broadleaf	Perennial	3.6
Malvaceae	<i>Sida acuta</i>	seeds	Broadleaf	perennial	2.1
Euphorbiaceae	<i>Croton hirtus</i>	seeds	Broad leaf		5.1
Amaranthaceae	<i>Altenanthera philoxeroides</i>	Vegetative	Borad leaf		1.5

Findings on the relative density of weed species showed that *Imperata cylindrica* recorded the highest percentage relative density and the most predominant in 2023 (56.4%) and 2024 (50.3%) followed by *Panicum maximum* in 2022 (23.3%) and in 2023 (25.9%). The consistent increase in relative density of the Poaceae family indicates its ability to adapt to the climatic condition in the two experimental sites and available resources, hence higher infestations on the crops (Table 9 and Table 10). The lowest percent relative density was recorded for *Calopogonium mucunoides* (1.1%) in the Fabaceae family in the 2022 cropping year (Table 8) and whilst in the 2023 cropping year, the lowest percent relative density was recorded for *Altenanthera philoxeroides* (1.5%) in the Amaranthaceae family (Table 10).

The study investigated the impact of agronomic management practices 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 yield with significant interactions between variety \times treatment, and treatment \times year factors (Table 10). Weed infestation was influenced by agronomic management practices

with a significant reduction observed in AMP 3 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 3 and 5 WAT, the weed quantity was notably lower in AMP 3 treated plots (2.66 and 6.03 weeds m⁻²) compared to APM 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 AMP 3 plots showing lower weed quantities at 3 and 5 WAT (4.06 and 7.33 m⁻²) compared to other treatments.

Table 10. Effects of variety and agronomic management practice on weed density.

Treatment	Weed density (weeds m ⁻²)			
	2022		2023	
	3 WAP	5 WAP	3 WAP	5 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
AMP 1	8.60 ± 0.10 ^b	15.30 ± 1.60 ^b	10.60 ± 0.20 ^b	18.33 ± 1.66 ^b
AMP 2	3.46 ± 0.03 ^c	6.36 ± 0.06 ^c	5.40 ± 0.13 ^c	9.33 ± 0.66 ^c
AMP 3	2.66 ± 0.16 ^c	6.03 ± 0.06 ^c	4.06 ± 0.16 ^d	7.33 ± 0.66 ^c
AMP 4	20.66 ± 0.60 ^a	60.60 ± 1.60 ^a	25.66 ± 0.66 ^a	61.67 ± 1.66 ^{ab}
F-Statistic				
Treatment (Pr > F)	<0.0001	<0.0001	<0.0001	<0.0001
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; AMP = agronomic management practice; CV = coefficient of variation.

Weed dry weight was significantly influenced by treatments in both years (**Table 11**). In 2022, AMP 3 plots had the lowest weed dry weight at 3 and 5 WAT (2.06 and 3.60 g m⁻²), followed by AMP 1 plots (4.33 and 5.33 g m⁻²), and AMP 4 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 3 and 5 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.).

Table 11. Effects of variety and agronomic management practice on weed dry matter.

Treatment	Weed dry weight (g m ⁻²)			
	2022		2023	
	2 WAP	4 WAP	2 WAP	4 WAP
Variety				
Heirloom	6.7 ± 0.53 ^a	8.4 ± 0.60 ^a	4.9 ± 0.23 ^a	6.8 ± 0.63 ^a
Nornro	6.8 ± 0.46 ^a	8.6 ± 0.16 ^a	5.0 ± 0.16 ^a	6.9 ± 0.65 ^a
AMP 1	6.96 ± 0.13 ^b	8.00 ± 0.10 ^b	4.96 ± 0.23 ^b	6.40 ± 0.20 ^b
AMP 2	4.33 ± 0.10 ^c	5.33 ± 0.06 ^c	2.33 ± 0.16 ^c	3.33 ± 0.16 ^c
AMP 3	2.06 ± 0.03 ^d	3.60 ± 0.30 ^d	1.06 ± 0.03 ^d	1.96 ± 0.03 ^d
AMP 4	13.66 ± 0.63 ^a	17.07 ± 0.33 ^a	11.66 ± 0.33 ^a	15.67 ± 0.33 ^a
F-Statistic				
Treatment (Pr > F)	<0.001	<0.001	<0.001	<0.001
Variety (Pr > F)	ns	ns	ns	ns
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; AMP = agronomic management practice; CV = coefficient of variation.

3.6. Effects of Variety and Agronomic Management Practice on the Number of Trusses, Flower and Fruit Yield

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 12). The Nornro variety outperformed the Heirloom 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 APM 1 plot recorded the highest numbers of trusses (24.0 and 22.3 plant⁻¹) and flowers (57.1 and 55.6 plant⁻¹) followed by AMP 3 for two years. Variety and biotic constraint management options significantly ($P < 0.05$) influenced fresh fruit yield during both 2022 and 2023 (Table 13). Nornro variety consistently produced higher fresh fruit yields of 3.5 and 3.4 t ha⁻¹) compared to the Heirloom variety (2.8 t ha⁻¹ and 3.1 t ha⁻¹) in

both years, respectively. APM 1 treated plots showed the highest fruit yield (5.3 t ha⁻¹ and 5.2 t ha⁻¹) closely followed by AMP 3 (4.6 and 4.4 t ha⁻¹) in 2022 and 2023, respectively. Overall, the fresh fruit yields for were slightly higher in 2022 than in 2023. AMP 4 plots consistently recorded the lowest fresh fruit yields across both evaluation years. These findings emphasize the significance of both variety selection and specific treatments, particularly AMP 1, in influencing the growth, flowering, and fresh fruit yield of tomato (Table 13). 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. The observed interactions between variety and treatment further highlight the need for a holistic approach in optimizing tomato crop production.

Table 12. Effects of variety and agronomic management practice 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				
Heirloom	12.4	36.1	12.5	36.7
Local (Nornro)	13.4	38.1	13.6	38.7
AMP 1	24.0 ± 1.0 ^a	57.1 ± 5.2 ^{ab}	22.3 ± 0.6 ^a	55.6 ± 4.4 ^a
AMP 2	14.0 ± 1.7 ^b	44.7 ± 4.0 ^b	13.7 ± 1.2 ^b	41.3 ± 3.7 ^b
AMP 3	22.3 ± 1.4 ^c	53.8 ± 2.0 ^d	20.4 ± 1.2 ^c	51.2 ± 2.3 ^d
AMP 4	8.1 ± 1.0.8 ^d	30.0 ± 1.8 ^e	7.3 ± 1.3 ^d	34.0 ± 0.6 ^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; AMP = agronomic management practice; CV = coefficient of variation.

Table 13. Effects of variety and agronomic management practice on fresh fruit yield of tomato.

Treatment	2022	2023
	Fresh fruit yield (t ha ⁻¹)	Fresh fruit yield (t ha ⁻¹)
Variety		
Heirloom	2.8 ± 0.2b	3.1 ± 0.3 ^a
Nornro	3.5 ± 0.2a	3.4 ± 0.3 ^a

Continued

AMP 1	5.3 ± 0.3 ^b	5.1 ± 0.3 ^b
AMP 2	4.0 ± 0.4 ^b	3.9 ± 0.2 ^b
AMP 3	4.6 ± 0.1 ^c	4.4 ± 0.1 ^c
AMP 4	2.5 ± 0.0 ^d	2.3 ± 0.0 ^d
F-Statistic		
Treatment (Pr > F)	<0.001	<0.001
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; AMP = agronomic management practice; CV = coefficient of variation.

3.7. Profitability of Tomato Production as Affected by Variety and Agronomic Management Practice

The revenue generated per hectare from the sales of tomato fruits differed considerably among different agronomic pest management options employed. The recommended treatment or agronomic pest management practice (AMP 1) generated the highest revenue in 2022 (NSLL 457.25) and 2023 (NSLL 487.60) evaluation years respectively (**Table 14**).

Table 14. Profitability of tomato production under different agronomic management practices in 2022 and 2023 cropping season.

Items (NSLL)	2022			2023		
	AMP 1	AMP 2	AMP 3	AMP 1	AMP 2	AMP 3
Yield (kg ha ⁻¹)	5.30	4.00	4.60	5.10	3.90	4.40
Cost of tomato (25 g)	38.75	38.75	38.75	40.00	40.00	40.00
Cost of chicken dung	57.6	0.00	0.00	57.60	0.00	0.00
Cost biofertilizer	0.00	120.00	0.00	0.00	60.00	0.00
Cost of NPK fertilizer	0.00	0.00	180.00	0.00	0.00	180.00
Cost of bio-pesticides (neem)	0.00	120.00	0.00	0.00	120.00	0.00
Cost of chemical pesticide	0.00	0.00	72.00	0.00	0.00	72.00
Cost of herbicides	0.00	0.00	48.00	0.00	0.00	48.00
Cost labour (Lump sum)	50.00	50.00	50.00	50.00	50.00	50.00
Total Cost (NSLL/ha)	107.60	290.00	350.00	107.60	230.00	350.00

Continued

Revenue (NSLL/ha)	457.25	310.00	384.78	487.60	310.80	449.20
Net revenue (profit) (NSLL/ha)	349.65	-40.00	94.78	380.00	-39.00	219.20

AMP = agronomic management practice; AMP 1 = 5 t ha⁻¹ Chicken manure + mulching + neem biopesticide; AMP 2 = 6 L ha⁻¹ biofertilizer, hand weeding at 1, 2 and 3 WAT + 30 ml 6 L H₂O⁻¹ ha⁻¹ neem extract (AZAGRO 3000); AMP 3 = pre-emergence herbicide promethrin + 88.9 kg ha⁻¹ NPK 15:15:15 + 6 ml 6 L H₂O⁻¹ ha⁻¹ chlorpyrifos; Control = no fertilizer, pesticide and herbicide applied.

The variables of producing tomato were differed among the different applied in both years of evaluation. The least variable cost was incurred by AMP 1 in both 2022 and 2023 (NSLL 107). The economic analysis revealed that AMP 1 produced the highest gross margin in both years of evaluation (NSLL 349.65) in 2022, and (NSLL 380.00) in 2023, respectively (**Table 14**).

4. Discussion

The findings of this study highlight the critical role of varietal selection and agronomic management practices (AMPs) in influencing tomato growth, pest and disease dynamics, weed infestation, and yield under suboptimal soil conditions. The soil analysis revealed low nitrogen levels, high acidity (pH < 6.5), and poor moisture retention before application of agronomic pests' management practices, but after the application of the agronomic management practices the physiochemical practices were improved which is consistent with findings by Brady and Weil [17], who noted that such conditions can severely limit crop productivity. The Heirloom variety showed superior growth indicators which was likely due to its genetic vigor, while the Nornro variety outperformed in flowering, truss formation, and fruit yield, possibly due to enhanced reproductive efficiency. The AMP 1-treated plots also showed superior growth and yield, which was likely due to improved soil organic matter and microbial activity [18]. This work also confirms the work of Obi and Ebo [19] who reported that organic amendments enhance soil-water-plant relations, leading to better crop performance. Bernardo *et al.* [20] found that integrating vermicompost and microbial inoculants with inorganic fertilizers significantly improved tomato yield and nutrient uptake. Another study by Minchev *et al.* [21] demonstrated that beneficial soil fungi such as *Trichoderma* and *Funneliformis* enhanced both tomato yield and resistance to *Tuta absoluta*. In contrast, AMP 3 (inorganic treatment) was most effective in suppressing whiteflies, leaf miners, and aphids, supporting Abbas *et al.* [22] on the efficacy of chemical pesticides. However, AMP 1 also showed notable pest reduction, likely due to bioactive compounds [23]. The Nornro variety demonstrated greater resistance to whiteflies and aphids, while the Heirloom variety was more resistant to leaf miners, highlighting the importance of host-plant resistance in integrated pest management (IPM). For disease management, AMP 3 and AMP 1 significantly reduced tomato mosaic virus and bacterial leaf blight incidence. The Nornro variety exhibited lower disease severity, possibly due to inherent resistance traits. The

higher disease pressure in 2023 compared to 2022 may be linked to climatic variations, as increased humidity favors pathogen spread Jones *et al.* [24]. Weed analysis revealed *Imperata cylindrica* and *Panicum maximum* (Poaceae) as dominant species, consistent with their aggressive growth (Norsworthy *et al.* [25]). AMP 3 (herbicide treated plots) had the lowest weed density, confirming synthetic herbicides' effectiveness [26]. However, AMP 1 also provided substantial weed control, likely through mulching and competitive exclusion [27]. Economically, AMP 1 generated the highest gross margin, demonstrating that organic-based management can be both sustainable and profitable, despite slightly lower yields than inorganic treatments. This supports the shift toward eco-friendly farming [28].

5. Conclusion

This study assessed organic and inorganic methods for improving tomato growth and managing pests, diseases, and weeds. Findings demonstrate that variety and crop management practices (organic and inorganic practices) boost tomato tolerance to pests and diseases, as well as its growth, yield and productivity that could be exploited for increased production and productivity of the crop. Agronomic management practice 1 (AMP 1), comprising chicken dung and *Gliricidia sepium* mulching, was the most effective in increasing vegetative growth and yield, followed by AMP 3 (inorganic management), while AMP 3 was the most potent in reducing pests' population and damage, disease incidence and severity, and weed infestation. AMP 4 (control) could not maximally support the crop partly due to poor soil structure and fertility status, pests and diseases attack and weed infestation and damage. The outperformance of the AMP 1 (organic treatments) relative to the AMP 3 and AMP 4 (inorganic and control) in increase growth and yield is suggested to be attributable to its nitrogen-rich components. Moreover, the agronomic management practices are environmentally friendly. Weed control was also established to be effective in both AMP 3 and AMP 1. Economically, AMP 1 was most profitable, highlighting the benefits of organic practices. The findings suggest that the AMP 1 should be promoted for sustainable tomato cultivation, prioritizing environmentally friendly methods for long-term success.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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