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Article

Effects of Agroecological-Based Techniques on Pest, Weed, and Disease Management in Orange-Fleshed Sweet Potato (OFSP)

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Abstract: Orange-fleshed sweet potato (OFSP) is a key biofortified crop for improving food and nutritional security in Sub-Saharan Africa, including Sierra Leone, however, its production is hindered by insect pests, diseases, and weeds. A field experiment was conducted in 2024 at Njala University, Sierra Leone, using a 3 × 4 factorial arrangement in a randomized complete block design (RCBD) with three replications to evaluate agroecological management techniques. Data were collected on vegetative growth, pest population and damage, diseases incidence and severity, weed density and yield, and analyzed using RStudio software. The results showed significant ($p < 0.05$) varietal and treatment effects on all measured parameters. Organic 1 significantly reduced aphid, tortoise beetle, and whitefly population (3.33–6.0 insect plant^{-1} at 12 weeks after planting) compared to control (13.67–13.78 insects' plant^{-1}), and a lowered disease severity score was observed which ranged from 1.0–1.2 at 12 weeks after planting compared to control (4.6–4.8). Organic 1 also produces the highest tuber yield (6.2 t ha^{-1}), outperforming the inorganic treatment (3.1 t ha^{-1}) and control (1.5 t ha^{-1}). In contrast, the inorganic treatment achieved the greatest weed suppression (4.5–4.9 plants m^{-2}) compared with the control (28.6–30.1 plants m^{-2}). Among varieties, Kaphulira recorded superior vegetative growth and yield, while Chipika exhibited relatively lower pest infestation. Integrating organic-based agroecological pest management, especially the combination of poultry manure and neem extract, provides an ecologically sustainable, productive alternative to sole reliance on synthetic inputs and enhanced OFSP productivity.

Keywords: Orange-Fleshed Sweet Potato; Agroecological Techniques; Pests; Diseases; Weeds; Management

1. Introduction

Orange-fleshed sweet potato (OFSP; *Ipomoea batatas* [L.] Lam.) is increasingly promoted as a low-cost, food-based strategy to reduce vitamin A deficiency (VAD) in sub-Saharan Africa (SSA), where inadequate vitamin A intake remains highly prevalent among young children and women of reproductive age [1,2]. OFSP storage roots are rich in β-carotene, a provitamin A carotenoid, and even modest daily consumption can meet a significant proportion of vitamin A requirements, thereby contributing to improved micronutrient status and helping to address public health burdens associated with VAD [1]. Adoption of OFSP has also been linked with broader food security and nutrition outcomes, as consumers adopt these varieties where extension, awareness, and value-chain support are present [2].

Sweet potato has long been a staple crop for resource-limited households due to its relatively short growing cy-

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cle, low external input requirement, and adaptability to marginal soils and climatic variability [3]. Breeding efforts in SSA have produced OFSP cultivars with enhanced drought tolerance and yield potential, while improved crop management practices have been shown to further increase productivity under smallholder conditions [3]. Despite these advances, adoption rates vary widely across countries and contexts, often reflecting differences in access to planting material, farmer awareness, and extension services [4]. Production constraints remain a major barrier to sustainable OFSP adoption. Farmers commonly cite biotic and abiotic stresses such as drought, pests and pathogens, lack of quality planting material, and low soil fertility as key limitations to yield and crop performance [3,5]. Among biotic stresses, viral diseases represent a critical challenge in SSA sweet potato systems. Surveys using molecular diagnostics have detected multiple viruses affecting sweet potato, including sweet potato leaf curl virus (SPLCV) and sweet potato symptomless virus 1 (SPSMV-1) as predominant pathogens in key production areas [6]. These viruses frequently occur in mixed infections with other agents such as cucumber mosaic virus (CMV), sweet potato feathery mottle virus (SPFMV), and sweet potato chlorotic stunt virus (SPCSV), potentially exacerbating yield losses and complicating disease management [6]. While these viral pathogens have been documented in West African contexts such as Benin, Côte d'Ivoire, and other regions, their presence underscores the need for integrated disease management strategies that incorporate clean seed systems and disease-resistant cultivars [6].

In addition to viral pressures, sweet potato weevils (*Cylas* spp.) and other insect pests can significantly reduce root quality and storage potential, highlighting the importance of integrated pest management (IPM) strategies that combine cultural, biological, and resistant-host approaches [7]. Soil fertility similarly limit OFSP productivity; although research suggests that balanced nutrient management including the combined use of organic amendments and inorganic fertilizers, can increase yields and agronomic efficiency, evidence remains relatively limited under smallholder conditions [4]. Despite the advances in OFSP breeding and nutrition research, relatively few studies have evaluated how holistic management packages integrating pest, weed, and disease control with soil fertility improvements and varietal choice influence vegetative growth, plant health, and marketable yields under smallholder conditions. This gap is especially pronounced in Sierra Leone and neighbouring West African countries, which have benefited less from OFSP dissemination programs compared with Eastern and Southern African contexts. The present study seeks to address this gap by assessing agroecologically based techniques that integrate organic and inorganic pest, weed, and disease management strategies among three OFSP varieties (Kaphulira, Mathuthu, and Chipika) under field conditions at Njala University, Sierra Leone. Specifically, the study examines impacts on vegetative growth, pest and disease incidence, weed dynamics, and root yield, generating context-relevant recommendations for sustainable OFSP production. By linking crop protection, soil fertility management, and varietal selection within an agroecological framework, this research contributes to the evidence needed to design OFSP systems that are nutritionally impactful, economically viable, and environmentally sound for smallholder farmers in SSA. Therefore, this study aimed to evaluate the comparative effectiveness of integrated organic and inorganic pest, disease, and weed management strategies on vegetative growth, pest and disease dynamics, weed suppression, and yield performance of three OFSP varieties (Kaphulira, Mathuthu, and Chipika) under field conditions at Njala University, Sierra Leone.

2. Materials and Methods

2.1. Description of the Experimental Site

The field experiment was conducted in June 2024 cropping seasons in the upland of the experimental site of the Crop Protection Department, School of Agriculture and Food Science, Njala University, Njala Campus in the Kori Chiefdom, Moyamba District, and South of Sierra Leone. The School of Agriculture and Food Science is located at an elevation of 5 m above sea level on a latitude of 8°6′ N and a longitude of 12°6′ W of the equator. Njala University, Njala Campus is located at about one hundred and fourteen miles (114) from the Capital city, Freetown, or Southern Sierra Leone, at approximately 7 miles off the Bo-Freetown highway. Njala University, Njala Campus experiences a distinct dry and wet season because of the denial nature of the area, the rainy season starts from April to November, and the dry season starts from October to May. The mean monthly air temperature ranges from 21 °C to 23 °C for the greater part of the day and night especially during the rainy season. Predominantly, the landscape of Njala University, Njala Campus is covered with secondary bush and consists of a well-balanced mixture of sand, clay, and humus. Before the trial, soil samples were collected at 20 cm soil depth using a soil auger at different points within the site, to determine any variation in certain physical and chemical parameters such as moisture content, primary nutrients concentration and acidity. The map of Sierra Leone shows clearly the study area (**Figure 1**).

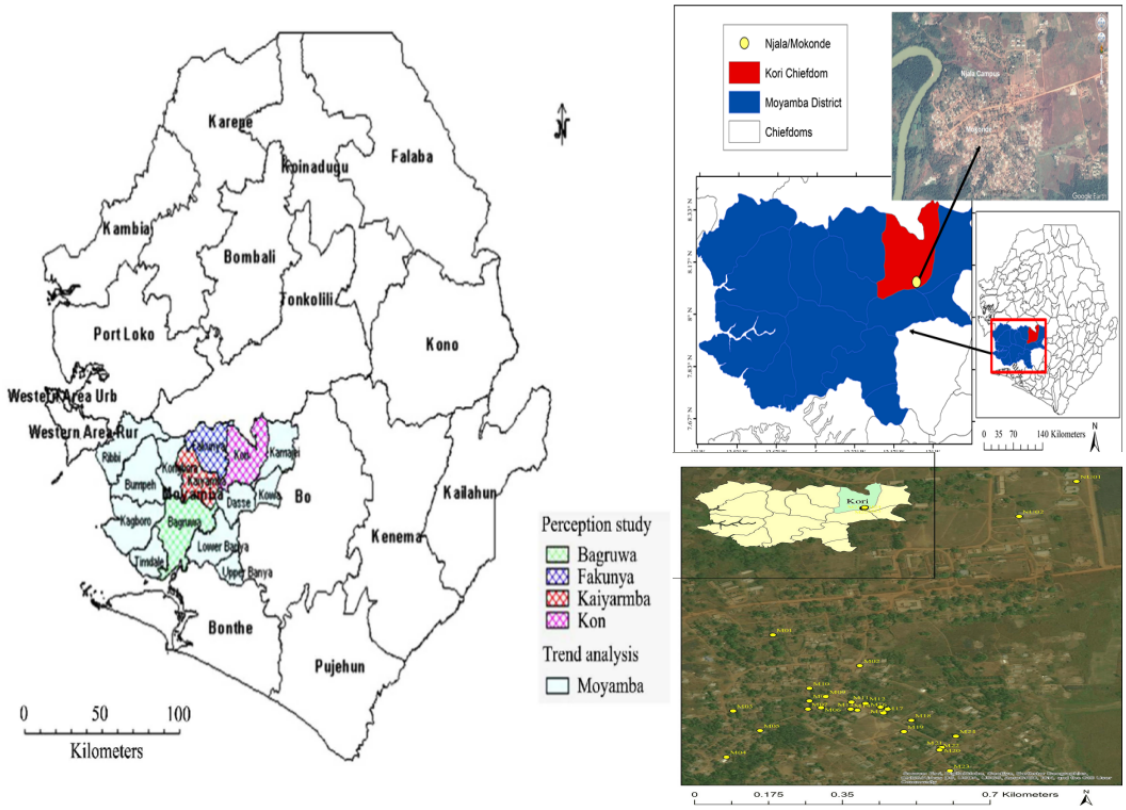

Figure 1. Map of Sierra Leone showing the study site.

2.2. Physico-Chemical Properties of Soil

Soil analysis showed persistently high acidity (pH 3.7–3.9) with low nitrogen and potassium and moderate phosphorus levels. Slight post-harvest nutrient increases suggest reliance on inorganic fertilizers, but without liming or sufficient organic amendments, soil acidity remained uncorrected. This limited nutrient availability, particularly phosphorus fixation under acidic conditions, promoted nutrient losses through leaching (**Table 1**). Overall, the results indicate a fertilizer strategy dominated by inorganic inputs, resulting in short-term nutrient gains but continued soil fertility decline and increased risk of long-term soil degradation.

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

Properties	Sampling in 2024 before Planting	Sampling in 2024 after Harvesting
Soil pH (1:1 H_2O)	3.9	3.8
Soil pH (1:1 KCl)	4.2	4.5
Nitrogen (N)	1.4	1.9
Phosphorus (P)	18.0	19.0
Potassium (K)	9.4	9.7

2.3. Experimental Design

The experiment was conducted as a 3 × 4 factorial in a Randomized Complete Block Design (RCBD) with three replications. The study evaluated the effects of three sweet potato varieties, Kaphulira, Mathuthu, and Chipika, under four management treatments: Organic 1, Organic 2, Inorganic, and a Control. This combination resulted in

12 treatment combinations, which were randomly assigned to 36 plots (12 treatments × 3 replications). The total experimental area was 595 m^2 (34 m × 17.5 m), with each plot measuring 3 m × 4 m (12 m^2). Orange flesh sweet potato vines were planted at a spacing of 0.9 m × 0.3 m, resulting in approximately 44 plants per plot. Border rows were maintained around the experimental area to minimize edge effects.

2.4. Treatment Breakdown, Preparation and Application

The experiment comprised three distinct crop management regimes integrating organic and inorganic nutrient and pest control strategies. The first regime consisted of an integrated organic nutrient and botanical pest control approach. Well-decomposed chicken manure was incorporated into the soil at a rate of 5 t ha^{-1} (approximately 300 g per planting hill) two weeks prior to planting to enhance soil fertility and organic matter content. Botanical pest management was achieved using an azadirachtin-based neem formulation (AZAGRO 3000; 0.3% azadirachtin, 3,000 ppm), applied at 25 kg ha^{-1}. The product was diluted at 2–3 mL L^{-1} of water according to the manufacturer's recommendation and applied using a calibrated knapsack sprayer. Applications were carried out at 4, 8, and 12 weeks after planting (WAP) when pest populations reached established economic threshold levels. Weed control was performed manually at 3 and 6 WAP.

The second regime involved the application of biofertilizer, botanical extract, and mulching. A mango-based fermented biofertilizer was applied at 200 L ha^{-1}, equivalent to 240 mL per 12 m^2 plot, one week after planting to stimulate microbial activity and nutrient availability. Botanical pest control consisted of an aqueous neem seed extract prepared by fermenting 30 g of neem seed powder (equivalent to 25 kg ha^{-1}) in 1 L of water for 24 h. Five grams of grated local soap were added as an emulsifying agent to enhance adhesion and spreadability. The solution was filtered and applied uniformly using a knapsack sprayer at 4, 8, and 12 WAP. Mulching was applied immediately after planting at 10 t ha^{-1}, corresponding to 12 kg of dry mulch material per 12 m^2 plot, to suppress weeds and conserve soil moisture. Manual weeding was also conducted at 3 and 6 WAP.

The third regime represented a conventional inorganic management system. Compound fertilizer (NPK 15:15:15) was applied at 300 kg ha^{-1} one week after planting. Weed control was achieved through pre-emergence application of promethrin herbicide at 4 L ha^{-1} (500 g L^{-1} active ingredient), applied two weeks before planting. Insect pest management involved the application of chlorpyrifos (480 g L^{-1} EC) at 4 L ha^{-1}, sprayed at 4 and 8 WAP when pest incidence exceeded the economic threshold level. The control regime involved no fertilizer, pest control, or herbicide applied and only minimal manual weeding once during the season.

2.5. Cultural Practices

The experimental field was manually cleared of vegetation, debris removed, thoroughly ploughed to a depth of about 10–15 cm and later raised into ridges using hoes and shovels. Vines of the three varieties (Matutu, Chipika, and Kapularia) were acquired from the research institution in Sierra Leone. Organic plots received organic compost, while inorganic plots received a balanced NPK 15:15:15 and urea fertilizer. OFSP vines were planted at a spacing of 30 cm × 90 cm.

2.6. Data Collection Procedure and Measurement

Data were collected systematically to evaluate vegetative growth, pest dynamics, disease development, and weed parameters throughout the cropping period. Standardized sampling procedures were adopted across all plots to ensure consistency and reliability of measurements.

Vegetative growth parameters were assessed at 4, 8, and 12 weeks after planting (WAP). Ten plants were randomly selected from the central rows of each plot to avoid border effects and ensure representative sampling. Vine length was measured in centimeters from the base of the plant to the apical tip using a measuring tape. The number of branches per plant was determined through direct counting, while the number of leaves per plant was also counted manually. Leaf area, expressed in square centimeters (cm^2), was estimated using standard leaf area estimation procedures. At harvest, the weight of the total number of tubers from ten tagged plants for each plot was recorded using a digital balance. The fresh tuber per plant was determined by dividing the total weight of the fruits by 10.

$$Fresh\ tuber\ weight\ per\ plant = \frac{Total\ weight\ of\ fresh\ tubers\ from\ ten\ hill}{10}$$

Pest population counts were conducted at 4, 8, and 12 WAP on the same ten randomly selected plants per plot. The number of major insect pests, including aphids, tortoise beetles, and whiteflies, was recorded per plant through visual inspection. Pest damage was estimated using a proportional leaf area assessment method. The total damaged leaf area per plant was visually estimated and expressed as a percentage of the total leaf surface area. The average percentage damage per plot was computed based on the ten sampled plants.

$$Insects\ plot^{-1} = \frac{Total\ number\ of\ insects\ from\ ten\ plants}{10}$$

$$Percentage\ leaf\ damage\ plot^{-1} = \frac{Total\ percentage\ leaf\ damage\ of\ insects\ from\ ten\ plants}{10} \times 100$$

Disease assessment was conducted concurrently with pest observations. Disease incidence was calculated as the percentage of symptomatic plants relative to the total number of assessed plants per plot using the formula:

Number of symptomatic plants/Total assessed plants × 100

Disease severity was evaluated using a 1–5 rating scale:
1 = No visible symptoms;
2 = Mild symptoms (≤25% leaf area affected);
3 = Moderate symptoms (26–50% leaf area affected);
4 = Severe symptoms (51–75% leaf area affected);
5 = Very severe symptoms (>75% leaf area affected or plant stunting).
Mean severity scores per plot were computed for analysis.

The incidence of diseases was determined as the percentage of symptomatic plants out of a total of ten plants, following the formula.

$$Incidence = \frac{Infected\ plants}{Total\ number\ of\ plants} \times 100$$

2.7. Weed Sampling

Weed density and biomass were assessed at 3 and 6 WAP. A 0.5 m^2 quadrat was randomly placed at two locations within each plot. All weeds within the quadrat were counted and expressed as plants per square meter (plants m^{-2}).

For biomass determination, weeds within the quadrats were harvested, oven-dried at 80 °C for 48 h, 1and then weighed. Weed dry weight was expressed as grams per square meter (g m^{-2}). Mean values per plot were used for statistical analysis.

2.8. Statistical Analysis

Data were subjected to two-way factorial analysis of variance (ANOVA) under a Randomized Complete Block Design (RCBD) using Software (Version 2.8). Prior to analysis, data were examined for normality using the Shapiro–Wilk test and for homogeneity of variance using Levene's test. Percentage data were arcsine square-root transformed where necessary to stabilize variances before conducting ANOVA. Where significant differences were detected, treatment means were separated using Tukey's Honestly Significant Difference (HSD) test at a 5% probability level ($\alpha = 0.05$).

3. Results

3.1. Vegetative Characteristics of Sweet Potato

The results presented in **Table 2** show that both variety and management treatment significantly influenced vine length, number of branches, number of leaves, and leaf area at 4, 8, and 12 WAP ($p < 0.0001$). In addition, the Variety × Treatment interaction was significant across all parameters, indicating that varietal response depended strongly on the management system applied.

Table 2. Effects of variety and management treatment on vegetative growth parameters of sweet potato during the 2024 main cropping season.

Effect	Vine Length (cm)			Branches Plant^{-1}			Leaves Plant^{-1}			Leaf Area (cm^2)		
	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP
Variety												
Kaphulira	58.3a	96.5a	137.9a	2.7a	3.1a	3.1a	28.6a	43.7a	62.0a	75.4a	133.5a	179.1a
Mathuthu	40.9b	59.5b	83.5b	1.8b	2.2b	2.5b	22.2b	30.6b	47.2b	47.3b	85.7b	104.9b
Chipika	29.7c	42.2c	53.9c	1.6c	1.6c	2.0c	15.5c	23.7c	37.9c	31.7c	46.0c	64.5c
LSD (0.05)	0.79	10.41	1.69	0.17	0.20	0.09	0.67	1.08	1.03	2.91	4.45	4.79
Treatment												
Organic 1	59.7a	92.2a	144.0a	3.2a	3.5a	3.7a	30.1a	47.7a	71.9a	95.9a	206.9a	243.7a
Organic 2	51.0b	67.7b	94.2b	2.2b	2.1b	2.5b	27.9b	32.4b	45.6b	58.4b	65.0b	88.2b
Inorganic	35.9c	57.5c	81.2c	1.4c	2.2b	2.2c	15.6c	27.8c	43.5c	30.7c	51.9c	75.2c
Control	25.3d	46.9d	53.9d	1.3c	1.5c	1.7d	15.0c	22.7d	35.1d	20.8d	34.8d	57.6d
LSD (0.05)	0.91	12.02	1.95	0.07	0.23	0.10	0.78	1.24	1.18	3.37	5.26	5.53
Pr > F (Variety)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Pr > F (Treatment)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note: Within each column, means followed by the same letter are not significantly different according to Tukey's HSD test at α = 0.05.

Among the varieties, Kaphulira consistently exhibited superior vegetative performance throughout the cropping season. It recorded significantly greater vine length at all sampling stages compared with Mathuthu and Chipika. Similar trends were observed for branch numbers, leaf production, and leaf area expansion, where Kaphulira maintained the highest values, followed by Mathuthu, while Chipika consistently recorded the lowest growth performance. The low coefficients of variation (2.2–7.0% for most parameters, except moderate variability at 8 WAP) indicate good experimental precision.

Management treatments also produced highly significant effects ($p < 0.0001$). Organic 1 consistently enhanced vegetative growth across all stages, producing the longest vines, highest branch numbers, greatest leaf counts, and largest leaf area. At 12 WAP, for example, vine length under Organic 1 exceeded control by more than 60%, while leaf area was more than four times higher than the control at early growth stages and remained substantially greater at later stages. Organic 2 improved growth relative to the control but remained inferior to Organic 1. The inorganic treatment showed intermediate performance, outperforming the control but generally remaining below both organic treatments.

The significant Variety × Treatment interaction ($p < 0.05$ across parameters) demonstrates that varietal ranking was not uniform under all management systems. Kaphulira showed the strongest positive response under Organic 1, where maximum vegetative growth was achieved. In contrast, varietal differences were less pronounced under the control treatment, reflecting constrained growth under suboptimal management conditions.

3.2. Incidence and Severity of Diseases

Significant differences ($p \leq 0.05$) were observed in the incidence and severity of Sweet Potato Virus Disease, Fusarium wilt, Leaf Spot, as well as in pest populations and leaf damage percentages among varieties, management treatments, and their interactions (**Tables 3** and **4**).

Among varieties, Kaphulira consistently exhibited the lowest disease incidence and severity throughout the growth period, with Fusarium wilt, virus incidence, and leaf spot severity declining steadily from early to late assessments. Mathuthu showed intermediate disease levels, whereas Chipika consistently had the highest incidence and severity. Pest populations and leaf damage followed similar varietal trends, with Kaphulira and Mathuthu recording lower pest densities and leaf damage than Chipika. Management treatments significantly influenced both disease and pest outcomes. Organic 1 consistently produced the lowest disease incidence and severity, minimized pest populations, and reduced leaf damage by approximately 30–40% relative to the control. Organic 2 provided moderate suppression, while the inorganic treatment achieved intermediate control. Control plots consistently recorded the highest incidence, severity, and pest damage, demonstrating minimal disease or pest suppression in untreated plots. The significant Variety × Treatment interactions ($p \leq 0.05$) indicate that varietal responses were strongly influenced by the management strategy. Kaphulira and Mathuthu benefited most from neem-based organic treatments, exhibiting the greatest reductions in disease severity and pest damage, whereas Chipika showed comparatively smaller improvements, reflecting inherent differences in varietal tolerance or susceptibility.

Table 3. Effects of variety and management treatment on disease incidence (%) of sweet potato during the 2024 main cropping season.

Effect/Treatment	SPVD			Fusarium Wilt			Leaf Spot		
	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP
Variety									
Kaphulira	47.4c	38.7c	10.8c	48.9c	37.1b	16.9c	45.4c	38.7c	10.7c
Mathuthu	56.2b	43.2b	21.3b	55.7b	42.1b	18.8b	54.2b	43.2b	21.3b
Chipika	61.7a	49.7a	30.1a	60.2a	37.1b	28.9a	59.7a	49.7a	28.1a
Pr > F	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
LSD (0.05)	2.52	1.69	3.45	2.39	1.02	0.19	1.28	2.01	1.80
Treatment									
Organic 1	31.1c	25.9c	22.1c	30.9c	23.1c	17.2c	29.1c	25.9c	24.1c
Organic 2	35.2b	31.5b	25.6b	34.9b	30.9b	20.9b	33.2b	31.5b	25.1b
Inorganic	37.2b	33.3b	29.9b	38.1b	32.8b	26.9b	37.2b	33.3b	28.9b
Control	47.1a	58.1a	60.2a	46.1a	55.9a	61.1a	44.1a	53.1a	66.2a
Pr > F	0.03	<0.001	0.01	<0.001	0.03	<0.001	0.05	<0.001	<0.001
Pr > F: V × T	0.05	0.02	0.05	0.03	0.016	<0.001	0.04	0.05	0.02
CV (%)	4.1	3.9	3.2	3.6	3.5	4.5	3.7	7.6	8.1

Note: Within each column, means followed by the same letter are not significantly different according to Tukey's HSD test at α = 0.05.

Table 4. Effects of variety and management treatment on disease severity of sweet potato during the 2024 main cropping season.

Effect/Treatment	SPVD Severity			Fusarium Wilt Severity			Leaf Spot Severity		
	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP
Variety									
Kaphulira	2.3b	1.9b	1.7b	2.3b	2.2b	1.8b	2.18b	1.94b	1.91b
Mathuthu	2.6a	2.0a	2.0a	2.6a	2.2a	1.8a	2.48a	2.25a	2.23a
Chipika	2.8a	2.0a	2.0a	2.7a	2.5a	2.2a	2.55a	2.51a	2.43a
Pr > F	0.05	<0.001	<0.001	0.10	<0.001	<0.001	0.19	<0.001	<0.001
LSD (0.05)	0.11	0.03	0.02	0.12	0.08	0.02	0.13	0.05	0.02
Treatment									
Organic 1	1.60c	1.40c	1.00c	1.7c	1.4c	1.10c	1.70c	1.40c	1.20c
Organic 2	2.30b	1.50b	1.40b	2.3b	1.7b	1.60b	2.00b	1.60b	1.30b
Inorganic	2.90a	2.40a	1.60a	2.9a	2.0a	1.10a	2.50a	1.20a	1.00a
Control	3.70a	4.60a	4.70a	3.7a	4.5a	4.60a	3.80a	4.40a	4.80a
Pr > F	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pr > F: V × T	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
LSD (0.05)	0.13	0.04	0.02	0.14	0.01	0.02	0.15	0.06	0.02
CV (%)	18.2	18.0	14.8	20.2	11.2	13.8	23.0	11.2	14.0

Note: Within each column, means followed by the same letter are not significantly different according to Tukey's HSD test at α = 0.05.

3.3. Number and Percentage Damage of Pests

Significant differences ($p \leq 0.05$) were observed in pest populations and leaf damage among varieties, management treatments, and their interactions, indicating differential varietal responses under specific management systems (**Tables 5** and **6**).

Overall, Chipika exhibited the lowest pest pressure and leaf damage, Mathuthu had intermediate values, and Kaphulira consistently recorded the highest pest populations and leaf damage throughout the growth period. These trends highlight inherent varietal differences in susceptibility to aphids, tortoise beetles, and whiteflies, as well as their associated leaf damage (%). Management treatments significantly reduced pest populations and leaf damage ($p < 0.05$). Organic 1 was the most effective, achieving the lowest pest densities and reducing leaf damage by approximately 30–40% compared to the control. Organic 2 provided moderate suppression, while the inorganic treatment performed comparably or slightly below Organic 1. The control plots consistently recorded the highest pest numbers and leaf damage, indicating minimal suppression in untreated conditions. The significant Variety × Treatment interaction ($p \leq 0.05$) revealed that Kaphulira and Mathuthu benefited most from neem-based treatments, showing greater reductions in pest pressure and leaf damage, whereas Chipika exhibited comparatively smaller improvements, reflecting varietal differences in tolerance or susceptibility.

Table 5. Effect of variety and management treatment on sweet potato pest populations (2024 main cropping season).

Factor	Aphids (Plants m^{-2})			Tortoise Beetles (Plants m^{-2})			Whiteflies (Plants m^{-2})		
	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP
Variety									
Kaphulira	10.5a	9.6a	8.8a	11.4a	10.4a	9.4a	10.0a	9.6a	9.17a
Mathuthu	8.5b	8.1b	6.7b	8.2b	7.5b	7.0b	7.2b	6.5b	6.75b
Chipika	7.0c	6.4c	5.5c	7.0c	5.9c	5.5c	5.5c	5.3c	4.8c
Treatment									
Organic 1	6.0a	4.8a	3.3a	6.6b	4.8a	3.8a	5.1a	4.1a	2.8a
Organic 2	6.5b	5.4b	4.2b	7.4b	6.3b	5.4b	6.5b	5.4b	4.3b
Inorganic	10.0c	8.8c	6.7c	9.4c	8.2c	7.4c	7.6c	7.2c	6.7c
Control	12.2d	13.1d	13.7d	12.0d	12.4d	12.5d	11.1d	12.0d	13.6d

Note: Within each column, means followed by the same letter are not significantly different according to Tukey's HSD test at $\alpha = 0.05$.

Table 6. Effect of variety and management treatment on leaf damage (%) caused by sweet potato pests (2024 main cropping season).

Factor	Aphids (%)			Tortoise Beetles (%)			Whiteflies (%)		
	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP
Variety									
Kaphulira	35.3a	31.5a	27.5a	36.0a	32.7a	27.3a	35.9a	33.1a	29.5a
Mathuthu	27.0a	26.2b	21.8b	27.9b	24.7b	21.1b	28.4b	25.7b	21.5b
Chipika	22.4c	20.4c	18.5c	22.5c	20.3c	18.9c	24.0c	21.2c	19.4c
Treatment									
Organic 1	20.4a	18.1a	14.8a	21.8a	18.2a	14.5a	21.6a	19.3a	15.5a
Organic 2	26.5b	23.8b	19.6b	25.6b	22.5b	16.1b	27.1b	23.2b	17.5b
Inorganic	30.0c	25.0c	19.6c	31.2c	25.5c	20.0c	31.1c	25.2c	20.1c
Control	36.0d	37.3d	16.3d	36.5d	37.4d	39.2d	38.0d	39.1d	40.6d

Note: Within each column, means followed by the same letter are not significantly different according to Tukey's HSD test at $\alpha = 0.05$.

3.4. Weed Density and Weed Dry Weight (g m^{-2})

Weed density (plants m^{-2}) and weed dry weight (g m^{-2}) were significantly influenced by management treatments and the Variety × Treatment interaction ($p \leq 0.05$), while varietal differences alone were not statistically significant ($p \geq 0.05$) (**Table 7**). Across varieties, Chipika consistently exhibited the lowest weed density, followed by Mathuthu, while Kaphulira recorded the highest weed pressure throughout the growing period. Early weed density at 3 WAP was lowest in Chipika (≈11.1 plants m^{-2}) and highest in Kaphulira (≈12.3 plants m^{-2}), with similar trends observed at 6 WAP (22.2–25.4 plants m^{-2}). Management treatments strongly affected weed populations. Inorganic treatment plots recorded the lowest weed density at both 3 WAP (≈4.5 plants m^{-2}) and 6 WAP (≈4.9 plants m^{-2}), attributed to the pre-emergence herbicide effect. Organic treatments with mulching (Organic 1 and Organic 2) showed progressive weed suppression by 6 WAP, demonstrating the combined effect of mulching and manual weeding. The control plots, where weeding was performed only once, consistently exhibited the highest weed density (≈28.6 plants m^{-2} at 3 WAP and 30.1 plants m^{-2} at 6 WAP). Weed dry weight followed similar trends. Chipika recorded the lowest weed biomass, followed by Mathuthu, whereas Kaphulira accumulated the highest biomass. Inorganic-treated plots significantly reduced weed biomass across all varieties at 3 WAP (≈5.7 g m^{-2}) and 6 WAP (≈3.1 g m^{-2}). Organic 2 plots achieved moderate reduction through mulching and manual weeding, while control plots exhibited the highest biomass at 3 WAP (≈15.6 g m^{-2}) and 6 WAP (≈17.5 g m^{-2}). These results demonstrate that management strategy rather than varietal differences predominantly drives weed suppression, with chemical control providing rapid early reduction and organic mulching contributing to sustained suppression over time. Standardized units were applied throughout: weed density as plants m^{-2} and weed biomass as g m^{-2}.

3.5. Yield Characteristics of Sweet Potato

Significant differences ($p < 0.05$) were observed in tuber number (plant^{-1}), total storage root yield (t ha^{-1}), and dry haulm weight (t ha^{-1}) among varieties, management treatments, and their interactions (**Table 8**).

Table 7. Effect of variety and treatment on weed density (plants m^{-2}) and weed dry weight (g m^{-2}) of sweet potato in the 2024 main cropping season.

Source	Weed Density (Plants m^{-2})		Weed Dry Weight (g m^{-2})	
	3 WAP	6 WAP	3 WAP	6 WAP
Variety (V)				
Kaphulira	12.3a	25.4a	8.6a	10.9a
Mathuthu	11.5a	24.3a	8.4a	10.1a
Chipika	11.1a	22.2a	8.1a	9.8a
Pr > F	ns	ns	ns	ns
LSD	0.68	0.63	0.71	0.24
Treatment (T)				
Organic 1	4.8c	5.3b	8.8b	3.7b
Organic 2	4.6c	5.1b	6.5c	3.4b
Inorganic	4.5c	4.9b	5.7d	3.1b
Control	28.6a	30.1a	15.6a	17.5a
Pr > F	<0.001	<0.001	<0.001	<0.001
LSD	0.79	0.72	0.82	0.28
V × T	ns	ns	ns	ns
CV (%)	8.5	16.0	10.2	10.0

Note: Within each column, means followed by the same letter are not significantly different according to Tukey's HSD test at α = 0.05.

Table 8. Effect of variety and nutrient management on tuber yield components during the 2024 main cropping season.

Factor	Treatment	Number of Tubers ($Plant^{-1}$)	Tuber Weight (t ha^{-1})	Dry Haulm Weight (t ha^{-1})
Variety				
	Kaphulira	5.6a	6.1a	4.7a
	Mathuthu	4.7b	4.9b	3.7b
	Chipika	3.8c	4.2b	3.2b
	Pr > F	<0.001	0.05	<0.001
	LSD (0.05)	1.71	1.01	1.75
Nutrient Management				
	Organic 1	42.5a	6.2a	4.1b
	Organic 2	38.5a	4.5b	5.3a
	Inorganic fertilizer	23.6b	3.1c	4.0b
	Control	10.0c	1.5d	2.5c
	Pr > F	<0.001	0.02	0.05
	LSD (0.05)	10.87	1.24	1.99
Interaction (V × N)		<0.001	0.04	<0.001
CV (%)		15.7	10.6	12.0

Note: Within each column, means followed by the same letter are not significantly different according to Tukey's HSD test at α = 0.05.

Across varieties, Kaphulira consistently demonstrated superior yield performance, producing the highest tuber number, storage root yield, and dry haulm biomass. Mathuthu showed intermediate performance, while Chipika recorded comparatively lower but relatively stable yields across treatments. These results confirm the significant influence of varietal genetic potential on yield expression. Management treatment significantly affected total storage root yield (t ha^{-1}). Organic 1 produced the highest yield across varieties, followed by inorganic management, while Organic 2 achieved moderate yield improvement but remained significantly higher than the control. Yield increases under Organic 1 ranged from approximately 22–35% relative to control plots, demonstrating the productivity advantage of integrated organic nutrient and botanical pest management. The control consistently recorded the lowest values for tuber number, storage root yield, and dry haulm weight.

The significant Variety × Treatment interaction ($p < 0.05$) indicates that yield response was variety specific. Kaphulira showed the greatest yield response under Organic 1 management, reflecting strong compatibility between its genetic potential and agroecological practices. In contrast, Chipika displayed comparatively smaller yield gains across treatments, suggesting more limited responsiveness to intensified management.

3.6. Discussion

The superior pest suppression observed under the Organic 1 treatment aligns with the well-established biochemical activity of neem (*Azadirachta indica*). Neem-derived formulations contain azadirachtin and related limonoids that function as insect growth regulators, antifeedants, and oviposition inhibitors. Azadirachtin disrupts ecdysteroid and juvenile hormone signaling, interfering with molting and reproduction, and leading to progressive population suppression [8]. Recent reviews confirm that neem-based bioinsecticides remain effective in vegetable and root crop systems and are compatible with integrated pest management due to reduced non-target toxicity [9,10]. Their sublethal and behavioral effects reduce pest fecundity and feeding damage without the ecological disruption commonly associated with broad-spectrum insecticides. Beyond direct pest suppression, the improved yield performance under Organic 1 reflects the contribution of organic nutrient inputs to plant vigor and soil function. Organic amendments enhance nutrient synchronization via microbial mineralization and improve root proliferation and nutrient uptake efficiency [11]. Long-term field experiments demonstrate that organic fertilization significantly improves soil organic carbon, aggregate stability, and crop yield stability compared with exclusive mineral fertilization [12,13]. Improved plant nutritional status enhances defensive compound production and structural resistance to herbivory, strengthening tolerance mechanisms in crops [14].

Organic inputs also modify soil microbial communities, which are central to nutrient cycling and biological disease suppression. A global meta-analysis demonstrated that organic farming systems significantly increase microbial biomass and enzymatic activity compared with conventional systems [15]. More recent long-term studies confirm that organic management enhances microbial diversity and functional gene abundance associated with nutrient cycling [16]. Beneficial rhizosphere microorganisms, including *Trichoderma* and *Pseudomonas* spp., suppress soil-borne pathogens via competition, antibiosis, and induction of systemic resistance (ISR) [17,18]. Advances in rhizosphere microbiome research further highlight the role of microbial networks in improving nutrient acquisition and plant immune responses [19]. These mechanisms likely contributed to the reduced disease incidence and yield stability observed under Organic 1 management.

The significant Variety × Treatment interaction indicates genotype-dependent utilization of ecological processes. Crop genotypes differ in root architecture, carbon exudation patterns, and nutrient use efficiency, which influence microbial recruitment and rhizosphere functioning [19,20]. Recent studies demonstrate that plant genotype shapes microbial assembly and soil feedback processes, affecting productivity under organic amendments [20]. Varieties with more extensive root systems may therefore benefit more strongly from organic inputs through enhanced microbial symbiosis and sustained nutrient release. In contrast, inorganic treatments achieved effective early weed suppression due to the rapid biochemical action of synthetic herbicides that inhibit essential metabolic pathways in weeds [21]. Weed competition remains a major contributor to global crop yield losses, and early suppression improves resource capture during critical growth stages [22]. However, effective weed control alone did not translate into superior yield in this study. While mineral fertilizers provide readily available nutrients, long-term dependence on synthetic inputs has been associated with reduced microbial diversity and altered biological functioning [16,23]. Reduced soil biological activity can compromise nutrient retention efficiency and resilience to biotic stress. Meta-analyses comparing diversified agroecological systems with conventional agriculture indicate that yield gaps can be significantly reduced when ecological processes such as soil health, crop diversification, and biological pest regulation are optimized [24,25]. Recent global assessments emphasize that sustainable intensification strategies relying on biological interactions and soil regeneration can enhance productivity while reducing external inputs [26,27]. Overall, Organic 1 functioned as an integrated ecological management system combining botanical pest suppression, enhanced soil microbial functioning, and improved plant physiological resilience. While inorganic weed control achieved strong short-term suppression, it lacked the synergistic soil-plant-microbe interactions necessary to maximize yield under the agroecological conditions of this study. These findings reinforce the relevance of ecological intensification approaches in OFSP production systems.

4. Conclusions

In conclusion, this study demonstrates that integrating organic inputs, specifically neem-based formulations combined with chicken manure and *Gliricidia sepium* mulch (Organic 1), can effectively reduce pest and disease pressure while enhancing sweet potato plant vigor and storage root yield. The findings highlight the agronomic and ecological value of combining botanical pest control with organic nutrient management within an integrated production system. From a practical perspective, we recommend that smallholder farmers operating under similar agroecological conditions adopt the Organic 1 approach as a sustainable and environmentally responsible management strategy. The use of locally available organic resources, together with neem-based pest suppression, provides a feasible pathway to reduce dependency on synthetic agrochemicals while maintaining productivity.

Nevertheless, the study was conducted at a single location and within one cropping season, which may limit broader generalization across diverse environments and years. Multi-location and multi-season evaluations are therefore necessary to confirm the stability of the observed responses under varying soil, climatic, and management conditions. Overall, the results support the integration of organic nutrient sources and botanical pest management into holistic crop management frameworks aimed at improving soil health, strengthening plant resilience, and advancing sustainable sweet potato production systems.

Author Contributions

Conceptualization, V.A., A.E.S., and D.D.Q.; methodology, A.E.S., V.A., and D.D.Q.; software, V.A. and J.M.; validation, V.A., A.E.S. and D.D.Q.; formal analysis, V.A., J.M. and D.D.Q.; investigation, C.B.J. and V.A.; resources, C.B.J.; data curation, C.B.J., J.M., V.A., and D.D.Q.; writing—original draft preparation, V.A. and J.M.; writing—review and editing, A.E.S. and V.A., visualization, V.A.; supervision, A.E.S. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

Data will be available upon request, and it will be provided by the corresponding author.

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Conflicts of Interest

The authors declare no conflict of interest.

AI Use Statement

AI like ChatGPT was used to strengthen the grammar of the manuscript.

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