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ORIGINAL RESEARCH ARTICLE

Effects of integrated cropping strategies on soil chemical properties and biological diversity in *Solanum tuberosum* production

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Abstract

Solanum tuberosum (potato) is one of the most important food crops in Kenya, but its productivity is below average due to constraints associated with biotic and abiotic factors. The study aims to determine the effect of integrated cropping strategies for improved soil health and biological diversity in Potato Production. Field experiment was conducted to investigate the effect of integrated cropping strategies *viz*. organic soil amendments, intercropping and biological control agents on soil health, and surface and rhizosphere biological diversity in potato production from May - August 2022. Soil health parameters ranged as follows: pH (6.5–6.7), nitrogen (0.2–0.4%), potassium (10–32 mg/kg), organic carbon (1.8–5.4%), and exchangeable potassium (0.18–0.23 meq/100g). Treatments T6 and T7 showed the most improvement across these indicators. The distribution of arthropod pests under Treatment T5 (potato planted alone) showed that whiteflies were the most prevalent (31.6%), followed by spider mites (26.5%), aphids (26.1%), and *Tuta absoluta* (7.9%). In the same treatment, the rhizosphere biological diversity included nematode genera such as *Tylenchus, Aphelenchus, Filenchus, Meloidogyne*, and potato cyst nematodes. The maximum initial late blight disease severity was observed on treatment *Solanum tuberosum* alone with a mean value of 32.93%. The highest bacterial wilt disease severity was recorded in treatment Solanum alone (79.73%), followed by Solanum + Common beans+ organic fertilizer (74.33%), and Solanum + *Trichoderma asperellum* + Organic fertilizer (65.90%). The lowest bacterial wilt severity was observed in *Solanum* with common bean (60.33%) and followed by treatment Solanum + banana fibre, and Solanum + organic fertilizer (62.60 % and 63.73%, respectively). In contrast, the highest late blight disease incidence was recorded in treatment Solanum + organic fertilizer (80.00%). In conclusion, the present study provides a novel understanding of the effect of integrated cropping strategies on the soil health and above and below ground biodiversity in the production of potato.

Keywords: Solanum Potato, Integrated cropping strategies, biological diversity, soil health, JKUAT

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1.0 Introduction

Potato is a crucial crop in East Africa, including Kenya, providing a significant source of food and income for many farmers (Mburu et al., 2020)). They grow well in varied climates particularly in the highland areas with cool temperatures including central highlands, rift valley and parts of eastern region (Mburu et al., 2020). This is typically due to well-drained, fertile soil and moderate climate with adequate rainfall. Different varieties including local and introduced types such as "Kenya Mpya, "Shangi" and "Fungu" are grown due to high yield potential, disease resistance and adaptability to local condition.

The common challenges affecting potato farming include, late blight (*Phytophthora infestans*) (Ivanov et al., 2021), early blight (*Alternaria solani*) (Chaerani et al., 2007)), bacterial wilt (*Ralstonia solanacearum*), potato cyst nematodes (*Globodera spp*) and viral diseases such as Potato virus Y (Ababa, 2024)). These diseases always attack the leaves, stems, tubers leaving dark or brown spots hence reducing the tuber quality and productivity. According to (Chaerani et al., 2007), different management strategies have been employed. For instance, resistance varieties, proper spacing for ventilation, fungicide application and crop rotation, but this has not managed to address these problems.

Integrated Crop Management (ICM) is a system of farming designed to enhance the sustainability of agricultural production through the conservation and protection of soil, water and biological resources (Page *et al*., 2020). Conservation agriculture (CA) has been promoted as a system capable of achieving the sustainable intensification required to meet world food demand (Kassam *et al*., 2009; Lal, 2015). Practices such as integrated pest and nutrient management are often incorporated into the CA system on a site-specific basis to help ensure its success (Lal, 2015; Thierfelder *et al*., 2018). A key driver to the improvements observed in the CA system is improved soil health, through greater levels of soil organic matter (SOM), especially at the surface of the profile, and the associated improvements in soil structural stability, fertility, water retention and biological diversity relative to conventional agricultural systems (Lal, 2015).

Additionally, regenerative agriculture approach to farming and land management aims to restore and enhance the health and resilience of agricultural ecosystems (Chaerani et al., 2007)). Unlike conventional farming, which often focuses on maximizing yield through chemical inputs and monoculture practices, regenerative agriculture emphasizes building soil health, increasing biodiversity, and improving the overall ecosystem (Sher et al., 2024)).

Soil management practices to maintain or improve soil quality can include application of organic and inorganic fertilizers, practicing rotations, or fallowing, and installing trenches for soil and water conservation (Zinn, 2011). The dynamics between cropping systems, soil management, and soil

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types need to be studied to better understand their influence on soil quality and fertility. The stability of ecosystems and ecological resilience is often indicated by arthropod species composition (Zinn, 2011). However, intensive agricultural activities can result in soil disturbance, decreasing biodiversity and disrupting the agricultural landscape (Sidauruk & Sipayung, 2018). Given that potato cultivation involves substantial soil movement, particularly during ridging, the soil is heavily exposed to erosion processes. With continuous cultivation, the soil becomes degraded with varying fertility gradients related to the length of continuous cultivation. Cultivating potato on such degraded soils results in not only low yield but also denies the soil its natural ability to revitalize (Ireri, 2018; Mallory & Griffin, 2007).

In Kenya, potato is the second most important food crop after maize and mostly cultivated by smallholder farmers for income generation and a source of food (Monke *et al.,* 2019). It plays a major role in national food security, while the demand for potato continues to rise, especially by urban consumers (Monke *et al.,* 2019). Emerging markets for processed potatoes have increasingly focused attention on potatoes, with increasing demand from the fast-food industry and processing for value addition (Ireri, 2018). However, the mean potato yields are way below optimal due to various factors, such as unreliable rainfall patterns, low soil fertility and pests (Ireri, 2018). Therefore, the need for integrated cropping strategies is essential in boosting potato production Kaguongo *et al*., 2008.

To address key production challenges in potato cultivation, this study evaluated the effectiveness of sustainable management strategies, including the use of Trichoderma asperellum as a biological control agent, organic fertilizer, intercropping with common bean, and banana fiber wrapping. These approaches have shown potential in improving soil health, enhancing plant resilience, and reducing pest and disease pressure, thereby contributing to improved crop productivity and sustainable potato farming systems. (Were *et al.*, 2013). The current study aims at establishing the effect of integrated cropping strategies on soil health, and above or below ground biological diversity in potato production for increased potato productivity.

2.0 Materials and methods.

2.1 Study site.

The research was carried out at the Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Juja, Kenya (Latitude: -1.09690 S, Longitude: 37.01540 E, 1519 m asl), from May-August 2022 under drip irrigation. Juja's climate is classified as warm and temperate, receiving an annual high temperature of 24.9℃, an annual low temperature of 14.7 ℃ and ~129.81 mm of rain per annum.

2.2 Experimental design and layout.

The experiment was arranged in a Random Complete Block Design (RCBD) and consisted of seven treatments per block, replicated four times. Plots measured 10 m x 2.3 m with 0.5 m path between

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plots and 0.7 m between blocks. A 1.0 m border crop of potato was planted around the trial). The treatment in each block were as follows; i) Potato planted in soil amended with an organic fertilizer (T1), ii) Potato planted in soil treated with *Trichoderma asperellum* (T2), iii) Potato intercropped with common bean (T3), iv) Potato tuber wrapped with treated banana fibre (T4), v) potato planted alone (T5), vi) Potato intercropped with common bean and in soil amended with an organic fertilizer (T6), vii) Potato planted in soil treated with *Trichoderma asperellum* and organic fertilizer (T7) . The rate of application for T7 was 500 g/ha through drenching for at a seven-day interval per application. The physiochemical properties namely pH, Electrical conductivity (EC) and cation exchange capacity (CEC) were determined in each treatment.

2.3 Treatments source and application.

Certified potato cv Shangi was sourced from Agricultural Development Corporation-Molo, Nakuru County. The land was prepared by tractor ploughing, and then harrowed by hand. The potato tubers were planted in trenches dug by hand at a depth of 10 cm and a spacing of 20 cm x 60 cm. Planting and consequent weeding and field management was conducted by hand, and watered by drip irrigation three times a week.

Certified seeds of common beans cv Rose Coco was sourced from Simlaw Seeds Company Ltd, Nairobi-Kenya. In addition an organic fertilizer was sourced from Sanergy Ltd Company, Nairobi-Kenya. This fertilizer constituted of N 1-3%, P 1%, K 1%, Ca 5%, C 12%, pH 6.5 – 8.5, Moisture 15 - 25%, C/N ratio 20:1, Organic matter 20% and Inert materials 3%. Banana fibre paper (80 m long x 30 cm wide) treated with Fluopyram (nematicide; wettable powder), was obtained from the International Institute of Tropical Agriculture (IITA), Nairobi-Kenya. Before planting, Potato tubers were wrapped with the treated banana fibre paper that had been cut into smaller sizes of 15 cm x 10 cm before planting and thereafter planted following the stated spacing and depth. *Trichoderma asperellum* was sourced from Real IPM Ltd, Thika-Kenya. The *Trichoderma* application followed the directions of use as per the label guidance of 1 ml per Litre on a weekly basis for a period of 4 consecutive weeks after planting. All through the growing season, all the appropriate cultural practices were carried out namely: watering three times a week, weeding, application of selected fungicides and pesticides at the recommended rates where and when necessary.

2.4 Soil analysis

2.4.1 Determination of Total Nitrogen, Phosphorus, Carbon, and Potassium.

Total nitrogen content was determined as described by Nelson & Sommers, (1973). In brief, 10 mL aliquot of soil sample solution was transferred to the reaction chamber and mixed with 10 mL of 1% NaOH. They were streamed-immediately into 5 mL of 1% boric acid containing drops of the mixed indicator. The mixture was allowed to distillate for 2 min and the distillate was removed and titrated with 140 HCl until the indicator changed from green to pink. The steam was allowed to pass through the apparatus for 30 min. The percentage nitrogen was calculated using the formula;

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$$\%N\ in\ soil\ sample = \frac{(a-b) \times 0.1 \times v \times 100}{100 \times w \times al}$$

Where a= volume of the titer HCL for the blank, b= volume of the titer HCl for the sample, v = final volume of the digestion, w = weight of the sample taken and al = aliquot of the solution taken for analysis

The total phosphorus content in respective treatments was determined using the colometric method of ascorbic acid (Weaver & Soil Science Society of America., 1994). Briefly, 5 mL of the supernatant clear wet-ashes digest solution were mixed with 20 mL of distilled water. An aliquot of 10 mL of ascorbic acid reducing agent were added and mixed well. The sample absorbance was measured at 880 nm wavelength. Percentage phosphorus was calculated using the formulae;

$$P\ in\ sample\ (\%) = \frac{c \times 0.025}{w}$$

Where, c = the corrected concentration for sample solution; w = the weight of sample..

The percentage of carbon in soil samples from the different treatments was determined using the Walkley–Black method. as described by Shamrikova et al., (2024). Briefly, 0.3 g of soil samples were mixed with 2 ml of water. The solution was then added with 10 ml of 5% potassium dichromate solution and allowed to completely wet the soil. 5 ml H_2SO_4 was added and digested at 150°C for 30 min. It was allowed to cool and added 50 ml 0.4% barium chloride and allowed to stand overnight. The aliquot of the supernatant solution was used to measure the absorbance at 600 nm. The percentage carbon content was determined using the formulae;

$$Organic\ Carbon\ (\%) = \frac{(a-b) \times 0.10}{w}$$

Where a = concentration of chromic Cr3+ in the sample; b = concentration of chromic Cr3+ in the control; w = weight of soil taken for analysis.

For potassium the absorbance was taken at 766.5 nm and its percentage content was determined using the formulae;

$$K\ (\%) = \frac{(a-b) \times v \times f \times 100}{1000 \times w \times 1000}$$

Where a = concentration of potassium in the digest; b = concentration of the blank digest; w = the weight of sample; v = volume if the digest solution; f = dilution factor.

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2.5 Impact of integrated cropping strategies biological diversity in potato production.

2.5.1 Arthropods pests

Arthropod pests associated with Solanum tuberosum cultivation were identified through a combination of sampling methods designed to capture a broad spectrum of species. Visual inspections were conducted regularly on plant foliage to detect pests such as whiteflies and aphids. Sweep netting was employed to collect flying and canopy-dwelling arthropods, while yellow sticky traps were strategically placed to monitor pest populations over time. These complementary techniques provided a comprehensive understanding of pest diversity and abundance within the potato fields.

2.5.2 Nematodes diversity

Systematic sampling technique was used to collect soil samples from each treatment whereby, the soil sample from the top 15-30 cm was collected using an auger. The soil samples were placed into clean labelled containers for nematode analysis. The nematodes were extracted from 100 g of soil samples following the sieving and decantation procedure as proposed by Senthilkumar et al. (2021). Each soil sample was first taken into a 1 L beaker and mixed with tap water. The water suspension was then stirred thoroughly and decanted into another 1 L beaker using a sieve of 2 mm mesh size to remove the stones and large debris. Thirdly, the water suspension was then mixed further and decanted through a 1.0 mm, 850 µm and 250 µm mesh size sieve, and the material that was left on the sieve was collected in another 250 ml beaker and the extraction was repeated using the modified Baermann funnel method. The extracted nematodes were removed for 2 days, stored at 4°C, fixed in triethanolamine-glycerol fixative (TAF) and counted using an Olympus stereo-zoom microscope (Source?; model: SZX16), and simultaneously mounted on slides for identification to the genus level using various texts according to di Montanara et al., (2022). The identified genera were assigned to different functional guilds based on their trophic groups and life history strategies (Li et al., 2020).

2.5.3 Disease assessment

Disease assessment of potato late blight, early blight and bacterial wilt were monitored throughout the plant growing seasons in all treatments. Disease incidence was assessed on each treatment by randomly selecting five plants per plot. The percentage disease incidence was calculated using the formula:

$$Disease\ incidence = \frac{Number\ of\ diseased\ plant}{Total\ number\ of\ plant\ assessed} \times 100$$

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For disease severity, it was determined by estimating the percentage of leaf or root area affected by randomly selecting five plant leaves and roots from each plot and scoring them using a scale as described by Shutong et al. (2007).

$$Disease\ severity\ (\%) = \frac{Sum\ of\ individual\ numerical\ ratings}{No\ of\ plants\ scored\ \times maximum\ score\ on\ scale} \times 100$$

Area under the disease progress curve was calculated for each plot using the formula described by Campbell and Madden (2014).

$$AUDPC = \sum_{i=1}^{n-1} \quad 0.5(xi + 1 + xi)(ti + 1 - ti),$$

Where Xi is the cumulative disease severity expressed as a proportion at the observation, is the time (days after planting) at the ith observation, and in is the total number of observations. AUDPC values were expressed in percent days.

2.6 Data analysis.

All data, including soil attributes, arthropod pest diversity, nematode abundance, and disease assessments, were analyzed using SAS software. Graphical presentations were created with GraphPad Prism version 9.3. Non-metric multidimensional scaling and pairwise composition analyses were performed using R-studio. Nematode diversity indices, such as maturity index (MI), sigma maturity index, plant parasitic index (PPI), structure index (SI), and channel index (CI), were calculated using the NINJA online application.

3.0 Results.

3.1 Determination of soil analysis.

The physiochemical properties of the soil varied significantly between treatment classes (Table 3.0). More specifically, soil pH was significantly higher at treatment T2 (6.71±0.08). However, there was a significant difference ($F=1.33$; $p<0.05$) between T4 and other treatments. The electrical conductivity (EC) was recorded highest at treatment T6 (126.08±13.98) and lowest at treatment T5 (92.73±9.26). There was also a significant difference ($F=1.16$; $p<0.05$) in treatment T5 compared to other treatments (Table 3.0). The cation exchange capacity (CEC) differed ($F=1.51$; $p<0.05$) between treatment T3 and T5. However, the highest CEC was recorded in treatment T5 (61.77±4.56) while lowest CEC was recorded in treatment T2 (34.10±9.16).

3.2 Total Nitrogen and Phosphorus

The percentage of total nitrogen varied across treatments (Fig. 1). Treatment T1 showed significantly higher nitrogen content compared to T2, T4, and T5 ($p < 0.05$). However, no significant

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differences were observed between T1, T6, and T7, or among T2, T4, and T5 ($p > 0.05$). Overall, T1 (0.4%) recorded the highest nitrogen percentage, whereas T2 and T5 had the lowest values.

Phosphorus content also varied among treatments (Fig. 1). Treatment T7 recorded significantly higher phosphorus levels than T6, T5, T3, and T2 ($p < 0.05$). In contrast, no significant differences were detected among T1, T4, and T7, or among T2, T3, and T5, as well as between T1, T3, and T4 ($p > 0.05$). Despite this, T7 recorded the highest phosphorus content, while T2 and T5 had the lowest.

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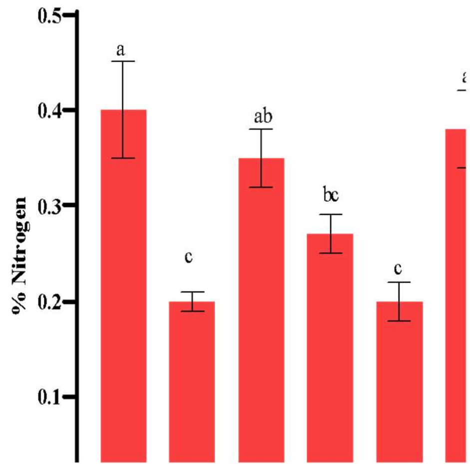

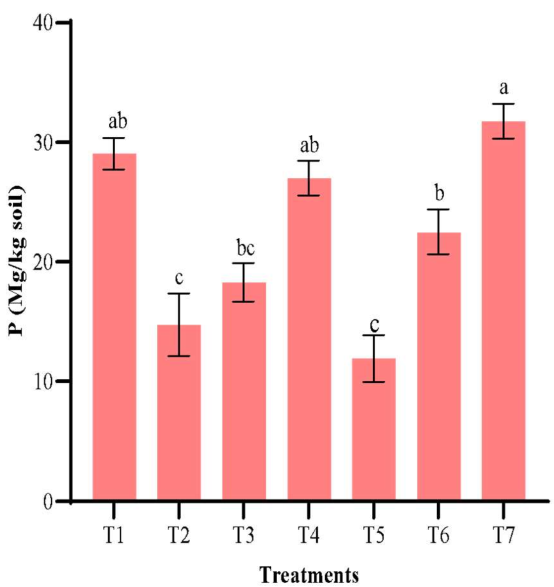

Fig. 1: Percentage of nitrogen and phosphorus based on Irish potatoes under different treatments.

The mean values with the same superscript letter(s) within the bar are not significantly different by the Fisher test. According to the Fisher's LSD test ($p < 0.05$), different superscript letters (a, b, c, d) indicate significantly different means. T1: Solanum potato with organic fertilizer; T2: Solanum potato with Trichoderma asperellum; T3: Solanum potato with common beans; T4: Solanum

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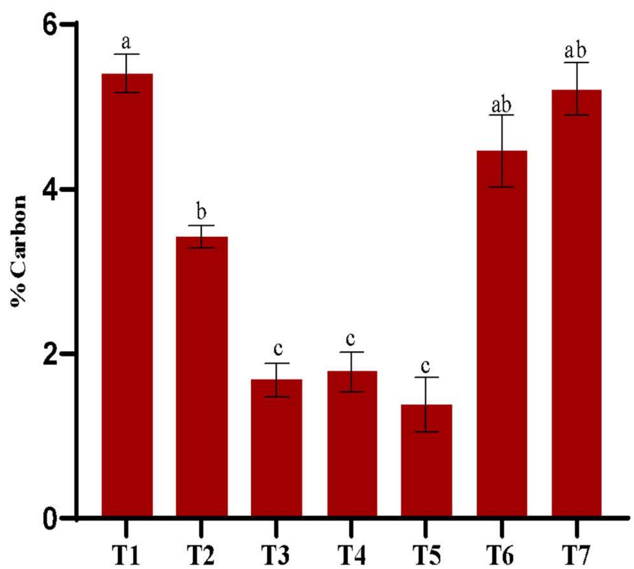
potato with banana fibre; T5: Control-Solanum potato alone; T6: Solanum potato with common beans and organic fertilizer and T7: Solanum potato with Trichoderma asperellum and organic fertilizer.

3.3 Total carbon and potassium

The total carbon varied across the treatments (Fig. 2). There was a significant difference ($p>0.05$) in the percentage carbon in Treatment T1 and treatments T2, T3, T4 and T5. However, there was no significant differences ($P>0.05$) among treatments T1, T6 and T7 (Fig. 2). Additionally, no significant difference ($p>0.05$) was observed in treatments T3, T4 and T5. Despite that, T1 () recorded the highest percentage of nitrogen while treatments T5, T3 and T4 recorded the lowest percentage carbon content respectively (Fig. 2). For the percentage of potassium recorded, there was a varied phosphorus content across all treatments. There was also a significant difference ($p>0.05$) among treatment T4 compared to other treatments. However, there was no significant difference ($p>0.05$) among treatments T1, T2, T3, T6 and T7 (Fig. 2). Despite that, Treatment T4 recorded the highest percentage of potassium while treatment T5 lowest percentage phosphorus



(Fig. 2).

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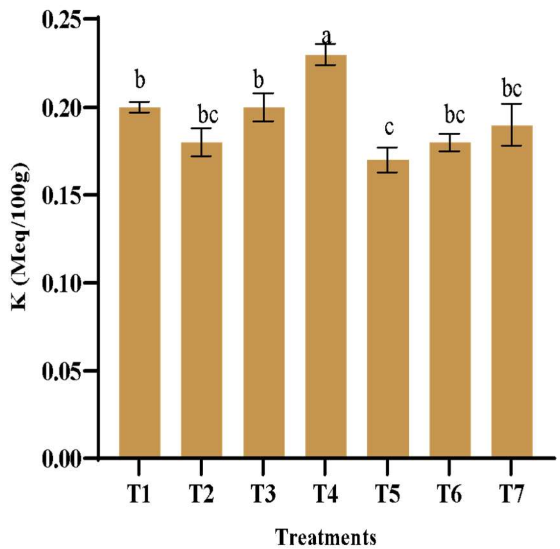

Fig. 2: Percentage of Carbon and potassium based on Solanum potatoes under different treatments.

The mean values with the same superscript letter(s) within the bar are not significantly different by the Fisher test. According to the Fisher's LSD test ($p < 0.05$), different superscript letters (a, b, c, d) indicate significantly different means. T1: Solanum potato with organic fertilizer; T2: Solanum potato with Trichoderma asperellum; T3: Solanum potato with common beans; T4: Solanum potato with banana fibre; T5: Control-Solanum potato alone; T6: Solanum potato with common beans and organic fertilizer and T7: Solanum potato with Trichoderma asperellum and organic fertilizer.

3.4 Determination of arthropod pest diversity.

The distribution of arthropods pests varied with white flies (31.6%) recorded the highest followed by Spider mites (26.5%), Aphids (26.1%) and *Tuta absoluta* (7.9%). Additionally, Bees (0.8%) recorded the lowest percentage followed by Lady bird's beetles (1.5%), Leafhoppers (2.1%) and Thrips (3.4%) (Fig. 3).

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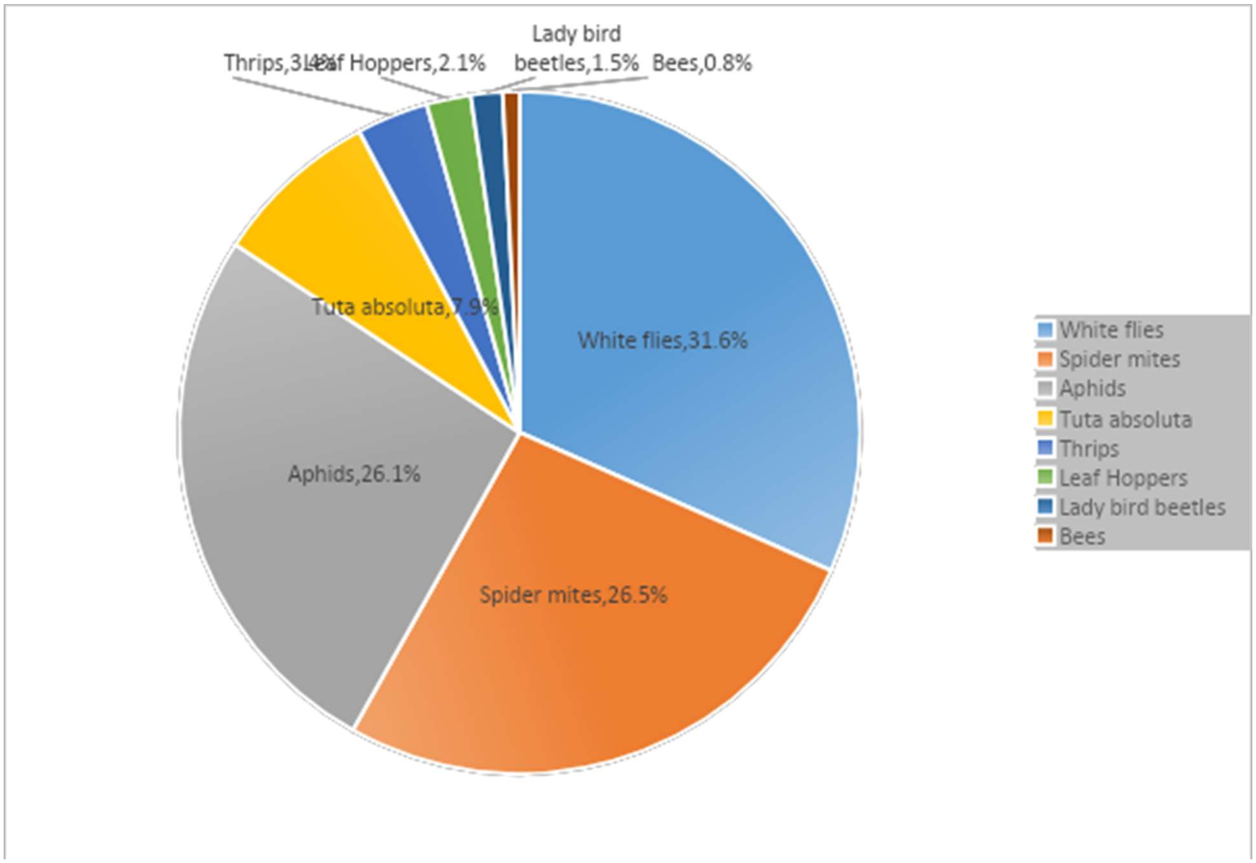

Fig. 3: Biological diversity of arthropods pests collected above the ground in the Solanum potato production

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The number of arthropods pest per treatment varied. For instance, Spider mites was recorded highest in treatment T5 (9) compared to other treatments. However, there was no significant difference ($F=0.04$; $p>0.05$) of recorded number of spider mites across all the treatments (Table 4). For Aphids, ($F=0.08$; $p>0.05$), Leafhopper ($F=0.21$; $p>0.05$), Thrips ($F=0.07$; $p>0.05$), White flies ($F=0.00$; $p>0.05$), *Tuta absoluta* ($F=0.07$; $p>0.05$), Bees ($F=0.66$; $p>0.05$) and Ladybirds ($F=0.27$; $p>0.05$) there was no significance difference in numbers across the treatments. Despite that, leafhopper, Bees, lady bird and thrips recorded the lowest number compared to mites, Aphids white flies and Tuta absoluta (Table 4.0).

3.5 Nematodes diversity

3.5.1 Soil nematode community composition at different treatments.

A total of 795 nematodes were collected belonging to 9 genera (Table 5). The NMDS analysis using Bray-curtis distance revealed that soil nematode community composition differed with different treatments (Fig. 4). All of the 9 genera identified differed significantly ($p>0.05$) among the treatments. For PCN (*Globodera* spp), there was significant difference ($F=0.947$; $p>0.05$) between

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treatment T4 (Banana fibres) compared to the rest of treatments. Additionally, treatment T4 recorded the lowest number of PCN compared to other treatments (Table 5; Fig. 4).

Also, the PERMANOVA analysis showed that nematode community composition differed significantly among the treatments both in terms of their relative abundances (F=0.0747; p>0.05). Furthermore, the pairwise analysis showed a statistically significant difference in the nematode composition between all treatments (Table 6).

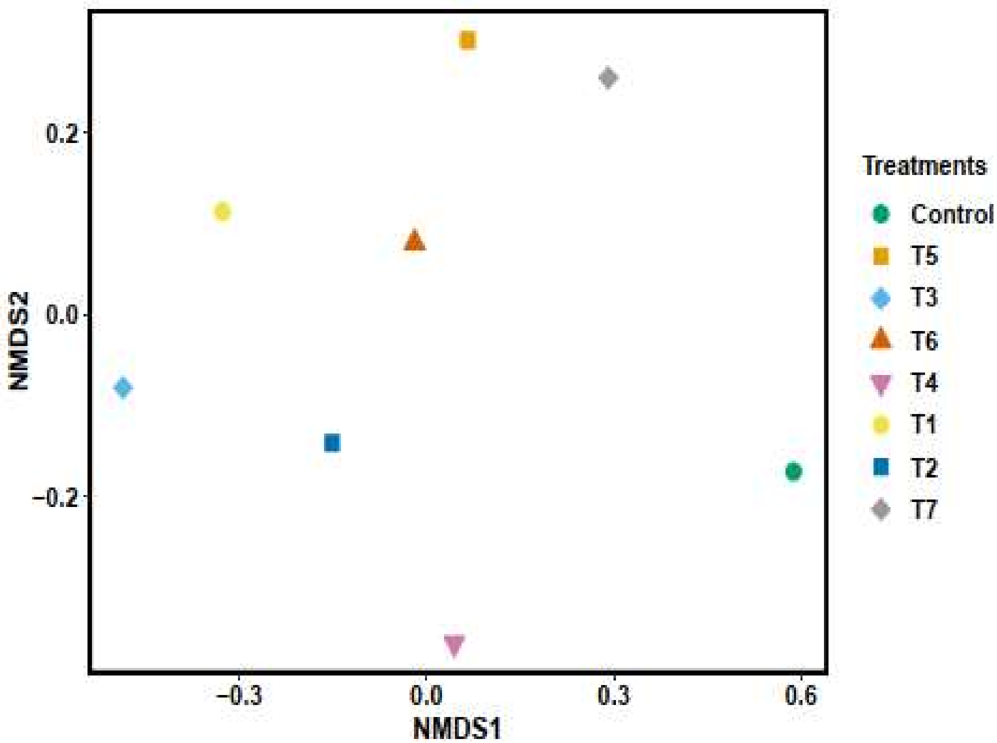

Fig. 4: Non-metric multidimensional scaling (NMDS) plot of nematode communities based on Bray–Curtis dissimilarity metric.

Each point represents the position of the nematode community in ordination space based on each individual treatment. T1: Solanum potato with organic fertilizer; T2: Solanum potato with *Trichoderma asperellum*; T3: Solanum potato with common beans; T4: Solanum potato with banana fibre; T5: Control-Solanum potato alone; T6: Solanum potato with common beans and organic fertilizer and T7: Solanum potato with *Trichoderma asperellum* and organic fertilizer.

3.5.2 Nemtode functional, diversity and metabolic indices.

Our study showed that among the nematode maturity indices, MI25 differed significantly (p<0.05) across the treatments, with highest value found at control (4.00±0.00) and lowest value at T3

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(2.00±0.000) (Table 7). Similarly, Plant Parasitic Index (PPI), Sigma Maturity Index (SMI), Basal Index (BI) and structural index (SI) differed significantly ($p<0.05$) across the treatments. However, Channel Index (CI) and Enrichment Index (EI) had no significant difference ($p<0.05$) across the treatments (Table 7). Our study also showed that among the various nematode composite structure and metabolic footprints, only Bacterivore footprint and predator footprint had no significant difference ($p>0.05$) across the treatments, while the remaining footprint varied significantly among the treatments (Table 7).

3.6 Disease assessment

3.6.1 Disease incidences

Potato late blight and bacterial wilt disease symptoms were assessed after 45 days after planting (DAP). The percentage of late blight disease incidences varied across the treatments, with T1 (80%) recording the highest incidence (Fig. 5). Treatment T5 (40%) and T7 (40%) recorded the lowest incidences compared to treatments T2 (60%), T3 (60%), T4 (60%) and T6 (60%). For Bacterial wilt incidences, the highest wilt was recorded in treatment T4 (60%), followed by T1 (40%) and T3 (40%) respectively. However, the lowest wilt incidences were recorded in treatments T2 (20%), T5 (20%), T6 (20%) and T7 (20%) (Fig. 5).

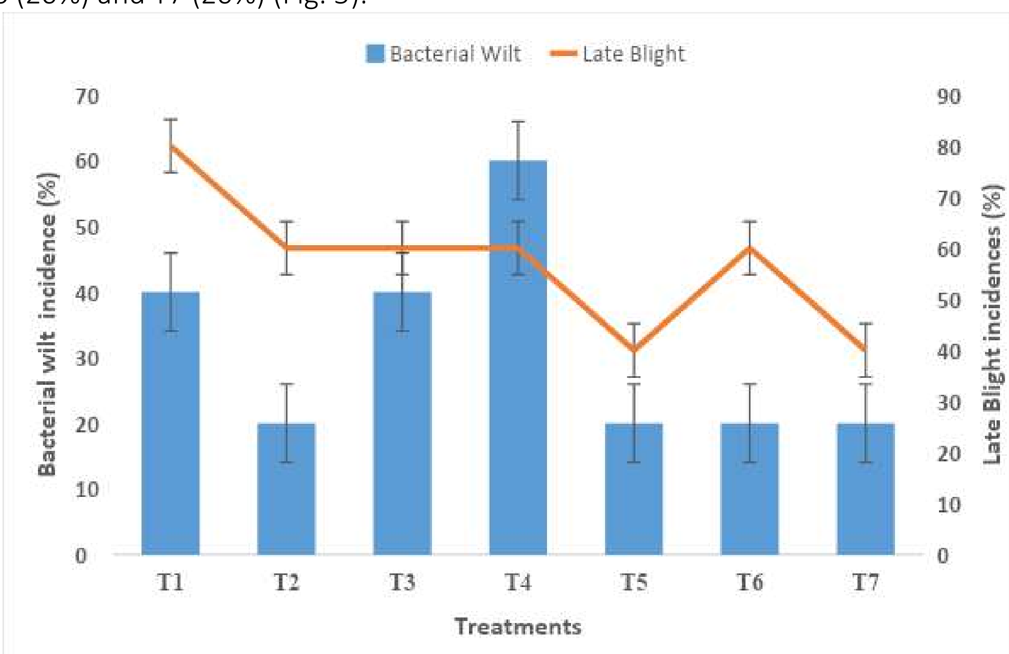

Fig. 5: Effects of different treatments on potato on bacterial wilt and late blight disease incidences after 45 DAP; T1: Solanum potato with organic fertilizer; T2: Solanum potato with Trichoderma asperellum; T3: Solanum potato with common beans; T4: Solanum potato with banana fibre; T5: Control-Solanum potato alone; T6: Solanum potato with common beans and organic fertilizer and T7: Solanum potato with Trichoderma asperellum and organic fertilizer. DAP: Days after Planting

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3.6.2 Disease severity.

The effects of different treatments on late blight and bacterial wilt disease severity showed a significant difference (p>0.005) among the treatments (Table 8). The maximum initial potato late blight disease severity was observed on treatment T5 with mean value of 32.93% followed by treatment T1 and T6 with 31.13 and 26.90% respectively (Table 8). The minimum initial potato late blight disease severity was observed in treatment T4 and T7 with 22.60%. After 6 weeks, there was recorded increase of late blight disease severity with highest recorded in treatment T6 (79.96%) followed by T5 (74.33%) and T7 (69.96%). The bacterial wilt disease severity was observed highest in treatment T5 (79.73%) followed by T6 (74.33%) and T7 (65.90%). The lowest bacterial wilt disease severity was observed in treatment T3 (60.33%) and followed by treatment T4 and T1 with 62.60 and 63.73% respectively (Table 8).

3.6.3 Area under disease progress curve (AUDPC).

The highest AUDPC value for late blight (1832.93%) and bacterial wilt (1879.43%) was recorded on treatment T5 whereas the lowest AUDPC value for late blight (1162.42%) and bacterial wilt (1165.12%). However, both late blight and bacterial wilt varied significantly (p>0.05) across the treatments (Table 9).

4.0 Discussion

Irish potato is the second most important food crop and source of complex carbohydrates, dietary fiber, and various vitamins and minerals. Therefore, integrated cropping strategies on the soil health, and above or below the ground biological diversity is important in Solanum potato production. Our study showed diversity of pH, EC and CEC at different treatments. The pH was neutral (6.55-6.71) with EC range of 92.73-126.08 and CEC range of 34.10-61.77. The results agree with the previous finding reported by Mugo et al., (2020) who reported a pH range scale of 3.9-6.6 as ideal for production of Solanum potato. Additionally, the pH affects the micronutrient and macronutrient of the soil and therefore affects the productivity of Solanum potatoes. According to Athanase et al., (2013), pH plays a big role in soil fertility and nutrient content of the soil. Acidic soil affects Phosphorus, Nitrogen, potassium and other macronutrients and therefore, lime is used to increase soil pH which favors soil microbial activities for organic matter decomposition. Similar results have also been reported by Nduwumuremyi et al., (2013) whose findings showed that pH>6.0 increased productivity of approximately 60% for six seasons. Despite that, EC is used to determine the total concentration of solute and reflects the salinity level of the soil. It has a critical effect on the germination, emergence and growth of the plant.

Irish potato farming relies heavily on the availability of key nutrients in the soil, including nitrogen, phosphorus, carbon, and potassium. These elements play vital roles in plant growth and development, directly influencing yield and quality. Our study recorded nitrogen 190-230 kg/ha (0.2-0.4%), potassium (14-33mg/kg/soil), carbon (1.9-5.8%) and potassium (0.18-0.24 meq/100g).

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Nitrogen is crucial for the growth of potato plants as it is a fundamental component of amino acids, proteins, and chlorophyll. It promotes vigorous vegetative growth and is essential for the development of foliage, which is necessary for photosynthesis. Insufficient nitrogen can lead to stunted growth and reduced tuber size, while excessive nitrogen can delay tuber maturity and increase susceptibility to diseases. The nitrogen range from our results agrees with previous studies on the required amount of nitrogen percentage content. According to Mugo et al., (2020), potatoes typically require 180-220kg/ha of nitrogen over the growing season. The content is distributed in pre-planting where approximately 30-40% of the total nitrogen should be applied before planting and post planting where the plant needs nitrogen for growth, side dressing, fertigation, tuber initiation and bulking to ensure continuous supply. Potassium is important for tuber quality, impacting size, starch content and resistance to disease. Our result agrees with previous findings on the required amount of potassium content for health growth of plants. According to Torabian et al., (2021) optimal production required considerable attention to the potassium requirement of potatoes. For maximum productivity, the content potassium above 20mg/kg/soil since it is taken up in large amount by the crop.

The amount of organic carbon is an indicator of soil health and fertility, impacting water retention and nutrient availability. Our results therefore agree with previous findings reported by (Niyonsenga & Mbaraka, 2012). According to Drakopoulos et al., (2018) higher organic carbon levels are beneficial for maintaining soil structure and nutrient supply. This supports overall soil fertility. Indirectly aiding nutrient uptake by potatoes. The incidence where carbon content was reported <10% the growth and yield were lower. In terms of phosphorus, our result concurs with findings reported by (Kelling et al., 2020). According to Jin et al., (2024) phosphorus is essential for energy transfer and root development, which directly influences tuber initiation and growth. Phosphorus content above 20 mg/kg is optimum level to enable improvement of tuber quality and yield. Phosphorus availability is critical during the early stages of potato growth, hence affecting the overall productivity of the crop (Akoto et al., 2020).

Despite ensuring the required amount of nutrient supply is achieved in Solanum potato farming, arthropods pests are a major concern in ensuring healthy crop yield. According to Sharma & Dhillon, (2018), various arthropods pose significant threats to potato crop and their diversity and impact vary depending on environmental conditions, geographical locations and farming practices. Our results reported the presence of aphids, mites, whiteflies, *Tuta absoluta*, thrips, leafhopper. The results agree with previous findings whereby (Shah et al., 2022), aphids have been linked to several potato viruses such as potato virus Y (PVY) and potato leafroll virus (PLV). According to Shah et al., (2022), the most common aphid species affecting potato are Green Peach Aphid (*Myzus persicae*) and Potato aphid (*Macrosiphum euphorbiae*). These aphids cause direct damage by feeding on plant sap causing stunted growth and distorted leaves (Rani et al., 2020). On other hand, mite species (*Tetranychus urticae*) attacks potato farming and feed on the undersides of the leaves causing stipping, yellowing and leaf drop (Jakubowska et al., 2022; Yaseen

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et al., 2021). High infestation of *Tetranychus urticae* reduced photosynthesis and weakened the plant. According to Sarwar, (2020) mite thrives in hot, dry conditions and can reproduce rapidly making them challenging to control once established.

The finding by Qasim et al., (2022) reported *Trialeurodes vaporariorum* commonly known as Green-house whitefly that causes mold growth on the leaves. Other findings include the Western flower Thrips (*Frankliniella occidentalis*) causing silvering or stippling on leaves and deformities in new growth (Rodrigues et al., 2023), potato leafhopper (*Empoasca fabae*) which are sap-feeding insect causing hopperburn (Chandel et al., 2022). Additionally, our results reported on the beneficial insects such as Bees and Ladybird. These findings are consistent with previous reports on the benefits of bees in pollination (Esquivel et al., 2021). According to Esquivel et al., (2021), potato plants are generally self-pollinating and do not rely heavily on insect pollinators. However, Esquivel et al., (2021) emphasized the importance of maintaining bee population in potato farms for overall biodiversity and health of the agricultural ecosystem. Ladybird on other hand is a beneficial arthropod since they act as natural predators of many potato pests such as aphids and mites. According to Shandilya et al., (2024), Ladybirds help in biological control (Integrated pest management strategy) and reduce the need for chemical pesticides.

The relative abundance study of nematodes plays a key role in understanding the large-scale patterns in biodiversity, global change and conservation. The present study showed that soil nematode diversity significantly differed among the treatments. Our result is in line with the findings of several studies conducted on biodiversity of Potato nematodes (Bairwa et al., 2022; Pulavarty et al., 2021). The variation in nematode richness and diversity is contributed by adverse climatic conditions. Our results showed the reduction of PCN in treatments with banana fibre. This agrees with the findings by (Ochola et al., 2022), who reported on the wrap and plant technology to manage sustainably potato cysts nematodes in East Africa. Additionally, it can also be contributed by vegetation composition, soil nutrients and soil physiochemical properties. All these biotic and abiotic factors shape soil nematode communities possibly due to net environmental filtering, varying environmental conditions and resource heterogeneity. Our study found that nematode abundance varied among trophic groups, with no bacterivores or predators detected, while fungivores were present at low abundance and herbivores at higher abundance. These results are consistent with previous reports that also observed a predominance of herbivorous nematodes in agricultural soils, highlighting their potential impact on plant health and soil ecosystem functioning (Ghaderi & Hamzezarghani, 2021; Malacrinò et al., 2021). Our findings also agree with a study by Lazarova et al., (2021) which reported that soil nematode trophic groups can exhibit differential response to different vegetative types. One possible reason for higher herbivore nematode abundance is the presence of well-developed dense root systems which provide shelter from various types of abiotic and biotic stress (X. Li *et al.,* 2022).

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According to Maureaud *et al.,* (2020), usage of functional and metabolic indices helps in understanding the mechanisms of ecosystem functioning. The present study evaluated several key functional and community indices to better understand both the relative contribution of nematodes trophic group to oil food web structure and changes in soil ecosystem functioning. Our result showed a lower value of maturity index (MI25) which varied significantly across the treatments. This decreased MI25 can be contributed by different soil amendments. According to Du Preez et al., (2022) maturity indices are indicative of degree of disturbance associated with the soil ecosystem hence there was comparatively higher degree of disturbance. Our study also found a decrease in SI but with a high PPI index although, there was no significant difference for CI index across the treatments. The CI index is the ratio of fungivore to bacterivore nematodes which were low and therefore the result indicates there was low nematode biomass generated as a result of fungal decomposition. Similar findings have been reported by Liu *et al.,* (2020).

The disease assessment was to assess the disease incidence, severity and Area under disease progress curve. Our study reported varied disease incidence with treatment having *Trichoderma* having the least disease incidence. The finding agrees with previous studies reporting that the application of Trichoderma harzianum reduced late blight and bacterial wilt in infected potato plants (Mollah & Hassan, 2023). Our results on disease severity showed significant differences among treatments. Similar findings have been reported in previous studies, where [biocontrol agents/treatments] were also shown to reduce disease incidence and severity in potato and other crops (Islam et al., 2021; Jihadi et al., 2023; Tiwari et al., 2021). Lastly, on areas under the disease progress curve, our results showed significant differences among all treatments. The results of the present study were consistent with the report of Kassaw et al., (2021).

5.0 Conclusion

The study provides a new insight of the effect of integrated cropping strategies on soil health and above and below ground biological diversity in the potato production. Overall, our study showed that different soil amendments have different soil attributes in terms of pH, EC and CEC. Additionally, different soil macronutrient content such as N, P, K and C affects the productivity of Solanum Potato. The study also showed that soil nematode diversity and community composition at different soil treatment could be due to shared effects of soil and other environmental factors. This therefore, enhances our understanding of the relative importance of various ecological drivers in governing nematode diversity and distribution pattern. Lastly, blight and bacterial wilt emerged as important diseases that require in the development of effective and sustainable management strategies to improve potato production

6.0 Acknowledgement

6.1 Data Availability

All the data are available upon request from the corresponding author

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6.2 Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

6.3 General acknowledgement

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