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Synthetic Fertilizer Application Coupled with Bioslurry Optimizes Potato (*Solanum tuberosum*) Growth and Yield

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Abstract: Biogas bioslurry, which is normally a bio-digestion product from livestock refuse, can be utilized as an inorganic fertilizer, thus boosting not only soil fertility but also crop growth and yield. Its use can mitigate climate change by reducing methane gas emissions, which are associated with the direct application of fresh animal manure. The current study was carried out on farmer's fields based at Wusi-Kishamba and Werugha wards in Taita Taveta County, Kenya, and it aimed at investigating the effect of bioslurry coupled with synthetic fertilizer on potato (*Solanum tuberosum* L.) growth and yield. There were four treatments: sole bioslurry, sole fertilizer (DAP), bioslurry + DAP, and control, which were replicated five times in a randomized, complete block-designed layout. Data were collected on plant growth (plant height and leaf length) and yield (marketable and unmarketable tubers and the number of tubers plant^{-1}). The results indicated a general increase in plant height from week one to week seven, where peak values were noted with sole slurry, sole fertilizer, and bioslurry + DAP treatments, which recorded 9, 18, and 43% taller plants, respectively, relative to control. Further, the combined application of bioslurry and DAP fertilizer significantly ($p \leq 0.05$) improved potato growth and yield. For instance, there was a higher (23.3 t ha^{-1}) yield in bioslurry + DAP treatment compared to the respective least record of 14.2 t ha^{-1} in control. Therefore, the study recommends a synergistic application of synthetic fertilizer (DAP) and bioslurry to potato crops for optimal crop growth and production.

Keywords: biogas; organic fertilizer; inorganic fertilizer; soil fertility; sustainable crop production

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1. Introduction

Potato is a high macronutrient-demanding crop, especially for potassium (K), phosphorus (P), and nitrogen (N), and insufficiency of any or combination of these nutrients can result in poor growth or total crop failure under extreme conditions [1–5]. Soil fertility decline has continuously been a great concern globally and a major barrier to agricultural productivity, which can be attributed to continuous cropping without adequate amendments [6,7]. Factors contributing to fertility decline include soil erosion, accumulation of toxic elements, and overdependency on synthetic fertilizers [8–10]. Agronomic practices such as continuous crop farming with inadequate use of fertilizers have resulted in low levels of soil organic carbon, which subsequently decreases microbial biomass [1,11,12]. Low yield production is attributed to poor agronomic practices and the unavailability of certified seeds and can be managed by the adoption of not only certified seeds but also integrated soil fertility management, which can help boost crop yields of up to 30 tons per hectare [13,14].

Synthetic fertilizers such as calcium ammonium nitrate (CAN), and di-ammonium phosphate (DAP) have been widely used in Kenya and exhibited a negative response to the environment [15]. Hence, organic fertilizers have been a promising factor in aiding nutrient availability [16]. For smallholder farmers, soil infertility is a fundamental biophysical root cause of reduced food production. This challenge, coupled with financial constraints, makes it hard for them to afford the full levels of recommended synthetic fertilizers [17]. In addition, there is a gap in understanding their applicability due to different synthetic element combinations aimed at boosting crop productivity.

Bioslurry, which is an anaerobically digested product from biogas digesters, can be applied foliarly to plants to supply the recommended nutrients [18]. The slurry is gaining popularity owing to the increasing demand for clean energy and has been a fundamental aspect of lessening environmental pollution and replacing the consumption of fossil fuels, which plays a critical role in sustainable development. The use of bioslurry in combination with synthetic fertilizer has great potential for increasing crop production, including potatoes. However, despite their great importance, the synergistic use of bioslurry and synthetic fertilizers has not been fully embraced by farmers. Therefore, the current study was carried out to (i) determine the effect of bio-slurry and inorganic fertilizer on the growth parameters of potatoes and (ii) evaluate the effect of bio-slurry and inorganic fertilizer on potato yield. The ultimate goal was to contribute to sustainable potato production.

2. Materials and Methods

2.1. Experimental Site

This field experiment was carried out during the 2020 short rains and 2021 long rains at Wusi-Kishamba and Werugha wards located in Taita Taveta County, Kenya. Wusi-Kishamba ward is located about 8.7 Km from Mwatate town and covers an area of 359 Km^2. It borders the Bura ward to the west, the Rong'e ward to the east, the Mwatate and Chawia wards to the south, and the Wundanyi/Mbale ward to the north. On the other hand, Werugha ward lies between the Ngangao Mountains (1952 m.a.s.l) and Iyale Valley (2104 m above sea level—m.a.s.l). The northern region of Werugha extends as far down as 1200 m.a.s.l and to the foothills of Taita.

The study region is comprised principally of well-drained, shallow, dark, very friable loam soils, eutrophic regosols, and lithic phases with acid humic and calcic cambisols [19]. During the study period, Werugha ward had the highest maximum (29.2 °C) and lowest (18.5 °C) temperatures compared to Wusi-Kishamba ward, which had values of 28.9 and 17.8 °C. In June, the lowest (15.9 and 15.4 °C for Werugha and Wusi-Kishamba wards, respectively) and highest (25.6 and 25.2 °C) temperatures were recorded. Wusi-Kishamba ward, on the other hand, experienced more rainfall (123 mm) than Werugha ward (96 mm) across the seasons. Across the wards, the maximum rainfall was obtained in November (70 mm) and April (94 mm), while the driest months were October and June, with 23 and 4 mm of rainfall, respectively. The farming systems in the area are comprised mainly of smallholder farmers who engage in both crop farming and dairy enterprises to meet the economic requirements of their families [20]. Cereals and horticultural crops are the main crops cultivated in the region.

2.2. Experimental Design, Layout, and Crop Husbandry

The experiment was laid out in five replicates in a randomized complete block design (RCBD). In this case, the experiment was set in five farmer's fields per ward, and therefore a farmer constituted a block. In each block, four treatments were tested: (1) control, without amendment (CT), (2) sole slurry, (3) sole fertilizer (DAP), and (4) combined bioslurry and 75% recommended DAP fertilizer. Each study plot measured 5 m wide and 6 m long. Inter-plot spacing was maintained at 0.5 m, whereas the respective inter-row and inter-seed spacings were 0.75 m and 0.30 m [20]. The destiny variety was chosen since it is commonly used by farmers within the region, and it was sourced from the National Potato Research Centre (NPRC). This variety was released by the NPRC in 2015/2016 and has good early growth, light to dark purple flowers, and dark green foliage, as well as resistance to diseases such as potato viruses Y and X and Erwinia spp. According to Araujo et al. [21], the variety is suitable for making crisps and suitable for all potato-growing areas with a maturity of about 3–4 months and a projected medium yield of 30–40 t ha^{-1}.

2.3. Soil and Bioslurry Sampling, Preparation, and Characterization

Soil characterization was carried out at the beginning of the experiment. Soil sampling was done from ten randomly noted points on the field by using an auger up to a depth of 30 cm. The samples were air-dried, ground with a mortar, and sieved with a 2 mm mesh. Bioslurry sampling was carried out by thoroughly stirring/mixing fresh bioslurry from biodigesters, drawing a 500 mL sample from the mixture, and packing it in a sampling bottle for analysis. The soil and slurry samples were analyzed for pH as outlined by Pansu and Gautheyrou [22] and explained by Ryan et al. [23]. The available P was extracted using the Olsen method [23]. Total N was analyzed using the Kjeldahl procedures as outlined by Willis et al. [24]. Exchangeable cations (Ca^{2+}, Na^{+}, K^{+} Mg^{+}, Mn^{4+} Cu^{2+}, Zn^{2+}, and Fe^{3+}) were determined using an atomic absorption spectrophotometer (AAS). In addition to these parameters, the slurry was analyzed for electrical conductivity (EC), HCO^{3-}, Cl^{-}, available $NH_4{}^{+}$, and NO_3, and additional exchangeable elements such as S^{2-}, Si^{4+}, Mo^{2+}, and Bo^{3+}. Total nitrogen and soil organic carbon (SOC) analyses were done only in soil samples using the Kjeldahl procedure as given by Willis et al. [24] and the modified Walkley-Black wet oxidation method [25].

2.4. Site Preparation, Planting, and Crop Management

Before the start of this study, cultivation was done before the onset of short (October 2020) rains. Fertilization was done at planting time in the rows where the fertilizer was mixed with soil to avoid seed scorching. Sowing was done during the short and long rain seasons, respectively. Medium-sized and well-sprouted tubers were planted, spaced at 0.30 m between tubers with an inter-row spacing of 0.75 m. The treatments were then supplied with the respective quantities of 50 t ha^{-1} of bioslurry and 50 kg ha^{-1} of Diammonium phosphate (DAP) fertilizer. Cultural practices such as disease, pest, and weed control were carried out uniformly in all plots. Weeding was effectively done through the use of a hoe, and in some instances, hand weeding was preferred. Hilling was done twice before flowering to avert the subjection of tubers to direct sunlight. To control early and late blight, spraying was done twice every month, commencing on the 14th day of crop emergence, using Daconil 720 SC (containing Chlorothalonil 720 g L^{-1}) with an alternation of Ridomil Gold MZ 68 WG, which contains Mefenoxam 40 g kg^{-1} and Mancozeb 640 g kg^{-1}. The stock solutions of the respective quantities of each chemical were prepared by dissolving them in half a liter of water and being made up to the required quantity of spray solution (spray volume) by adding water. The spray solution was dissolved in water as per requirement and applied with a knapsack sprayer by using the flat fan nozzle. All the necessary cultural practices were carried out uniformly to bring the crop to maturity.

2.5. Field Measurements and Statistical Analyses

In the field, the data were collected on potato growth parameters (plant height and leaf length) and potato yield attributes (number of tubers plant^{-1}, marketable and unmarketable tubers). Ten plants were selected randomly from the three inner potato rows and tagged for data collection. Quantitative data measurements were taken and recorded during the first week, when the potato had sprouted, until the harvest period in week 7. Crop growth and yield were studied, and measurements were made on a plot-by-plot basis. Plant height was measured from the ground (base of the plant) to the top part of the stem using a ruler and expressed in centimeters. The number of leaves per plant was determined by manual counting of the leaves from every tagged plant. Leaf length measurements were taken using a ruler, considering the entire compound leaf, and expressed in centimeters. At harvest, the tubers that were large-sized, healthy, and ≥50 g were regarded as marketable tubers, whereas those considered unmarketable were the ones that were either damaged by pests and diseases, weighed less than 50 g, were green, or were rotten [26,27]. The total tuber yield was computed by summing up the marketable and unmarketable yields [28].

The biophysical data obtained from this study were tabulated into an Excel spreadsheet and subjected to a general analysis of variance (ANOVA) using GenStat statistical software, version 2015. Further, the treatment means found to be remarkably disparate were segregated using Fishers' protected Least Significant Difference (LSD) at $p \leq 0.05$.

3. Results

3.1. Soil Fertility Status of Werugha and Wusi-Kishamba Wards

Analyses of the soil at the experimental sites indicated an extremely acidic status (pH = 4.2–5.0) in the Werugha ward to moderately alkaline (pH = 8.0–8.2) in the Wusi-Kishamba ward. The soil organic matter content ranged from 0.2 to 0.5%, whereas total organic carbon (TOC) had a range of 0.21 to 4.1% (Table 1). The bio-slurry used for this study was slightly alkaline (pH = 7.47) with an electrical conductivity of 7.5 mS cm^{-1} (Table 2). Its primary exchangeable cations: Ca^{2+}, Na^{+}, K^{+}, and Mg^{+} had respective values in cmol kg^{-1} of 0.26, 0.46, 2.37, and 8.48.

Table 1. Soil chemical characteristics at Werugha Wusi-Kishamba wards.

Ward	Soil Parameter	Minimum	Maximum	Target (Critical) Level
Werugha	pH	4.18	7.74	≥5.5
	Total organic carbon (%)	0.21	3.97	≥2.7
	Total nitrogen (%)	0.02	0.39	≥0.2
	Potassium (%)	0.06	1.29	≥0.24
	Available P (mg kg^{-1})	6.0	248	≥30.0
	Magnesium (%)	0.03	4.09	≥1.0
	Calcium (%)	0.2	7.9	≥2.0
	Copper (mg kg^{-1})	0.21	5.70	≥1.0
	Manganese (%)	0.01	0.54	≥0.11
	Zinc (mg kg^{-1})	0.96	14.4	≥5.0
	Iron (mg kg^{-1})	6.31	133	≥10.0
Wusi-Kishamba	pH	4.68	8.19	≥5.5
	Total organic carbon (%)	0.47	4.11	≥2.7
	Available P (mg kg^{-1})	5	270	≥30.0
	Total nitrogen (%)	0.05	0.41	≥0.2
	Potassium (%)	0.08	1.83	≥0.24
	Calcium (%)	0.7	7.9	≥2.0
	Magnesium (%)	0.56	6.00	≥1.0
	Manganese (%)	0.01	0.35	≥0.11
	Copper (mg kg^{-1})	0.28	4.17	≥1.0
	Zinc (mg kg^{-1})	0.58	18.9	≥5.0
	Iron (mg kg^{-1})	3.48	117	≥10.0

Table 2. Chemical characteristics of the bioslurry.

Parameter	Value
pH (water)	7.47
EC (mS cm^{-1})	7.56
NH_4^+ (mg kg^{-1})	153
NO_3 (mg kg^{-1})	3.88
Available P (mg kg^{-1})	28.5
Exchangeable K (cmol kg^{-1})	2.37
Exchangeable Ca (cmol kg^{-1})	0.26
Exchangeable Mg (cmol kg^{-1})	0.44
Exchangeable S (mg kg^{-1})	8.48
HCO_3 (mg kg^{-1})	4440
Exchangeable Fe (mg kg^{-1})	1.46
Exchangeable Mn (mg kg^{-1})	0.73
Exchangeable Zn (mg kg^{-1})	<0.01
Exchangeable Cu (mg kg^{-1})	0.13
Exchangeable Mo (mg kg^{-1})	0.014
Si (mg kg^{-1})	34.9
Exchangeable Na (cmol kg^{-1})	0.46
Exchangeable Bo (mg kg^{-1})	<0.01
Cl (mg kg^{-1})	705

3.2. Effect of Bioslurry and DAP Fertilizers on Potato Growth Indices

3.2.1. Plant Height

Synthetic fertilizer interaction with bioslurry resulted in significant ($p \leq 0.001$) taller plants across the seasons and wards relative to the sole application of these inputs (Table 3). Generally, the plant height increased moderately from week one to week seven, where peak values were noted, where it peaked at 56, 61, 66, and 80 cm for control, sole slurry, sole fertilizer, and bioslurry + DAP, respectively. Across the seasons, the average plant height was 34 cm for control, 38 cm for sole slurry, 43 cm for sole fertilizer, and 52 cm for bioslurry + DAP. The overall highest mean plant height across the weeks (54 cm) was recorded in the Werugha ward for the bioslurry + DAP fertilizer treatment, compared to the record of 50 cm for the Wusi-Kishamba ward. The least values (37 cm) and (32 cm) were obtained from treatment with no amendment (control) across the two wards. A similar trend was observed in sole slurry and sole fertilizer treatments, which had an average plant height of 42 cm and 47 cm in Werugha and 36 cm and 42 cm in Wusi-Kishamba wards throughout the 2020 short rain season, respectively. The 2021 long rain season had the highest average plant height with Werugha and Wusi-Kishamba wards' values that were such that control (35 cm, 34 cm) < sole slurry (36 cm, 37 cm) < sole fertilizer (42 cm, 41 cm) < bioslurry + DAP (52 cm, 54 cm).

Table 3. Plant height (cm) (means ± standard error) at Werugha and Wusi-Kishamba wards from sprouting (week 1) to maturity (week 7) as influenced by treatments in the 2020 short rains and 2021 long rains seasons.

Season	Ward	Treatment	Plant Height (cm) Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
2020 Short rains	Werugha	Bioslurry + Fertilizer	19.97 ± 3.38 [a]	29.72 ± 3.57 [a]	46.65 ± 5.77 [a]	57.52 ± 5.22 [a]	67.23 ± 3.39 [a]	73.99 ± 3.79 [a]	81.23 ± 3.88 [a]
		Sole Slurry	15.06 ± 2.26 [c]	23.84 ± 2.35 [c]	33.82 ± 6.29 [c]	43.91 ± 6.26 [c]	51.39 ± 3.56 [c]	59.96 ± 3.51 [c]	66.28 ± 3.02 [c]
		Sole Fertilizer	18.34 ± 3.88 [b]	27.03 ± 3.32 [b]	41.19 ± 5.79 [b]	49.18 ± 7.23 [b]	58.80 ± 5.24 [b]	64.74 ± 4.19 [b]	71.00 ± 1.97 [b]
		Control	12.48 ± 2.37 [d]	21.89 ± 2.18 [d]	32.55 ± 6.35 [c]	38.41 ± 6.58 [d]	45.36 ± 5.95 [d]	50.12 ± 5.31 [d]	56.88 ± 3.52 [d]
	Wusi-Kishamba	Bioslurry + Fertilizer	22.93 ± 6.21 [a]	33.81 ± 3.90 [a]	41.32 ± 3.78 [a]	50.06 ± 4.91 [a]	57.47 ± 4.48 [a]	65.73 ± 3.69 [a]	75.16 ± 2.76 [a]
		Sole Slurry	15.09 ± 3.14 [c]	23.52 ± 2.85 [c]	28.94 ± 2.75 [c]	34.41 ± 2.15 [c]	40.95 ± 4.77 [c]	51.26 ± 4.91 [c]	59.55 ± 4.72 [c]
		Sole Fertilizer	19.43 ± 6.07 [b]	27.88 ± 3.80 [b]	34.67 ± 4.57 [b]	41.70 ± 4.31 [b]	47.82 ± 5.54 [b]	57.28 ± 3.29 [b]	63.85 ± 4.04 [b]
		Control	10.98 ± 3.50 [d]	18.36 ± 2.45 [d]	24.67 ± 2.92 [d]	30.54 ± 3.20 [d]	36.71 ± 4.10 [d]	44.45 ± 4.08 [d]	53.77 ± 4.19 [d]
2021 Long rains	Werugha	Bioslurry + Fertilizer	22.59 ± 2.94 [a]	33.80 ± 3.85 [a]	42.53 ± 3.54 [a]	52.48 ± 4.25 [a]	62.20 ± 4.29 [a]	71.89 ± 4.57 [a]	81.74 ± 4.64 [a]
		Sole Slurry	14.17 ± 1.77 [c]	20.59 ± 3.33 [c]	28.39 ± 3.82 [c]	34.53 ± 4.03 [c]	43.03 ± 3.48 [c]	50.55 ± 3.13 [c]	58.59 ± 2.28 [b]
		Sole Fertilizer	15.90 ± 2.62 [b]	24.75 ± 5.29 [b]	33.46 ± 3.77 [b]	41.68 ± 4.48 [b]	51.54 ± 3.99 [b]	58.55 ± 3.15 [b]	65.16 ± 2.54 [b]
		Control	13.68 ± 2.10 [c]	21.40 ± 2.29 [c]	27.34 ± 1.93 [c]	35.00 ± 2.68 [c]	41.70 ± 3.34 [c]	48.79 ± 3.00 [d]	56.48 ± 2.65 [d]
	Wusi-Kishamba	Bioslurry + Fertilizer	25.41 ± 2.33 [a]	36.01 ± 1.54 [a]	44.29 ± 1.75 [a]	54.06 ± 2.25 [a]	63.69 ± 2.72 [a]	72.25 ± 3.95 [a]	81.98 ± 3.37 [a]
		Sole Slurry	14.38 ± 1.74 [c]	22.81 ± 1.64 [c]	30.19 ± 2.27 [c]	37.25 ± 2.64 [c]	44.58 ± 2.02 [c]	52.25 ± 3.10 [c]	60.13 ± 2.49 [c]
		Sole Fertilizer	17.50 ± 1.82 [b]	25.56 ± 1.64 [b]	34.00 ± 2.36 [b]	42.14 ± 2.87 [b]	49.38 ± 3.13 [b]	57.01 ± 2.39 [b]	64.19 ± 2.44 [b]
		Control	11.61 ± 1.76 [d]	20.44 ± 2.82 [d]	26.59 ± 2.94 [d]	34.39 ± 2.89 [d]	41.49 ± 3.07 [d]	48.49 ± 2.83 [d]	56.53 ± 2.33 [c]
		Summary of analyses of variance (p values)							
		Treatment (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		Ward (W)	0.008	0.007	<0.001	<0.001	<0.001	<0.001	<0.001
		T × W	<0.001	<0.001	0.022	0.710	0.092	0.473	0.035

Means bearing distinct alphabet letters (for every season and down the column) vary significantly at $p \leq 0.05$ by LSD test.

3.2.2. Leaf Length and Number of Leaves per Plant

Leaf length (LL) was significantly affected ($p \leq 0.05$) by treatments and wards, with the seasons having negligible effects (Table 4). As was the case with plant height, LL increased progressively from week one to week seven. Across the seasons and wards, the mean LL was such that control (18 cm) < sole slurry (23 cm) < sole fertilizer (24 cm) < bioslurry + DAP (28 cm). The highest mean LL of 39 cm and lowest 29 cm were attained from the combined bioslurry + DAP fertilizer and control treatments, respectively, with sole slurry and fertilizer treatments exhibiting respective intermediate values of 33 and 35 cm. A significant difference was observed between wards, where the 2021 long rain season had Werugha and Wusi-Kishamba having LL means of 23 cm and 24 cm, respectively, compared to values of 23 cm and 22 cm for the 2020 short rain.

Similarly, there was a significant ($p \leq 0.001$) effect of treatment on the number of leaves per plant (Table 5). As was the case with plant height, there were more leaves per plant from week one to seven. Across seasons, wards, and weeks, the average number of leaves per plant recorded was: control (9) < sole slurry (10) < sole fertilizer (12) < bioslurry + DAP (13). Seemingly, higher means of 14 and 13 and lower than 10 and 9 were recorded from Werugha and Wusi-Kishamba wards from bioslurry + DAP and control treatments, respectively.

3.3. Effect of Bioslurry and DAP Fertilizer on Potato Yield

Marketable, unmarketable, and the total number of tubers per plant were significantly ($p \leq 0.05$) influenced by DAP fertilizer and bioslurry (Table 6). Generally, in the 2021 long rains, potatoes had more tubers plant^{-1} (9) than those of the 2020 short rains (7). The least (2) and the uppermost number of marketable tubers plant^{-1} were obtained in control and bioslurry + DAP treatments, respectively, with intermediate values of 4 in sole slurry and 6 in sole fertilizer. Concerning the unmarketable number of tubers per plant, the average values in decreasing order were 7 (control) > 4 (sole slurry) > 3 (sole fertilizer) > 2 (bioslurry + DAP). Based on the total number of tubers per plant, there were 9, 7, 8, and 8 tubers recorded for every plant in control, sole slurry, sole fertilizer, and bioslurry + DAP treatments, respectively.

Similarly, the marketable, unmarketable, and cumulative tuber yields were significantly ($p \leq 0.05$) affected by fertilizer and bioslurry application (Table 6). The long rain season performed better (with an average yield of 13.0 t ha^{-1}) than the short rain season (10.2 t ha^{-1}). Based on the wards, Werugha performed better in comparison with Wusi-Kishamba, with a respective average marketable yield of 13.9 and 12.2 t ha^{-1}. Across the seasons and wards, in descending order, the mean marketable tuber yield was such that control (5.0 t ha^{-1}) < sole slurry (9.9 t ha^{-1}) < sole fertilizer (12.6 t ha^{-1}) < bioslurry + DAP (19.0 t ha^{-1}).

In contrast, the unmarketable tuber yield was highest (9.2 ha^{-1}) in control and least (4.4 t ha^{-1}) in bioslurry + DAP. The long rain season had a slightly high unmarketable tuber yield (7.2 t ha^{-1}) compared to the short rain season (6.0 t ha^{-1}). Further, concerning total tuber yield, control had the least (14.2 t ha^{-1}) whereas bioslurry + DAP had the highest value (23.3 t ha^{-1}) with intermediate values of 18.7 and 16.8 t ha^{-1} being noted in sole fertilizer and sole slurry treatments, respectively. Based on the seasons, 2021 long rains recorded a higher yield (20.3 t ha^{-1}) compared with 2020 short rains (16.2 t ha^{-1}). Werugha Ward exhibited good yield results across the seasons compared with Wusi-Kishamba Ward, with an average seasonal yield of 19 and 18 t ha^{-1}, respectively.

Table 4. Leaf length (cm) (means ± standard error) at Werugha and Wusi-Kishamba wards from sprouting (week 1) to maturity (week 7) as influenced by treatments in the 2020 short rains and 2021 long rains seasons.

Season	Ward	Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
			Leaf Length (cm)						
2020 Short rains	Werugha	Bioslurry + Fertilizer	12.27 ± 3.65 [a]	17.95 ± 2.45 [a]	22.88 ± 1.34 [a]	27.72 ± 1.71 [a]	30.93 ± 2.49 [a]	34.96 ± 1.96 [a]	38.53 ± 2.12 [a]
		Sole Slurry	12.40 ± 2.75 [a]	17.37 ± 2.39 [ab]	21.79 ± 2.03 [b]	24.60 ± 1.87 [b]	27.10 ± 1.87 [b]	29.98 ± 2.09 [c]	33.06 ± 1.67 [c]
		Sole Fertilizer	12.66 ± 2.78 [a]	17.04 ± 2.61 [b]	21.58 ± 1.76 [b]	25.03 ± 1.40 [b]	27.81 ± 1.19 [b]	31.44 ± 1.24 [b]	34.53 ± 1.32 [b]
		Control	7.79 ± 2.20 [b]	11.67 ± 2.25 [c]	15.39 ± 3.46 [c]	18.05 ± 3.50 [c]	21.26 ± 3.67 [c]	24.04 ± 4.20 [d]	27.45 ± 4.49 [d]
	Wusi-Kishamba	Bioslurry + Fertilizer	12.43 ± 2.49 [a]	19.38 ± 3.27 [a]	25.32 ± 2.78 [a]	29.01 ± 3.49 [a]	32.20 ± 3.52 [a]	35.32 ± 3.81 [a]	38.65 ± 2.20 [a]
		Sole Slurry	9.50 ± 1.23 [c]	14.34 ± 1.72 [c]	18.21 ± 1.06 [c]	21.85 ± 1.82 [c]	25.73 ± 1.93 [c]	28.46 ± 2.73 [c]	31.40 ± 2.30 [c]
		Sole Fertilizer	10.30 ± 1.39 [b]	15.97 ± 1.62 [b]	20.41 ± 1.07 [b]	24.38 ± 1.61 [b]	27.40 ± 1.87 [b]	31.14 ± 2.50 [b]	34.33 ± 2.23 [b]
		Control	8.68 ± 0.87 [d]	12.39 ± 1.14 [d]	17.08 ± 1.90 [d]	20.24 ± 2.46 [d]	23.83 ± 1.88 [d]	27.06 ± 2.08 [d]	30.99 ± 1.83 [c]
2021 Long rains	Werugha	Bioslurry + Fertilizer	13.23 ± 2.29 [a]	19.51 ± 2.79 [a]	25.02 ± 2.76 [a]	29.90 ± 2.87 [a]	32.99 ± 2.95 [a]	36.78 ± 2.07 [a]	39.65 ± 1.20 [a]
		Sole Slurry	12.76 ± 1.14 [a]	17.89 ± 2.24 [b]	21.58 ± 2.29 [b]	24.75 ± 1.80 [b]	27.44 ± 1.59 [b]	30.94 ± 1.97 [b]	33.03 ± 1.71 [c]
		Sole Fertilizer	12.47 ± 2.62 [a]	16.27 ± 1.91 [c]	21.00 ± 1.45 [b]	25.00 ± 1.24 [b]	28.04 ± 1.11 [b]	31.88 ± 1.24 [b]	35.03 ± 1.23 [b]
		Control	8.08 ± 2.25 [b]	11.23 ± 2.08 [d]	13.35 ± 2.54 [c]	16.18 ± 3.14 [c]	20.11 ± 3.39 [c]	23.30 ± 4.02 [c]	26.88 ± 4.70 [d]
	Wusi-Kishamba	Bioslurry + Fertilizer	12.98 ± 2.42 [a]	20.10 ± 3.26 [a]	26.62 ± 2.92 [a]	31.44 ± 2.68 [a]	34.46 ± 2.20 [a]	37.77 ± 2.29 [a]	39.81 ± 1.21 [a]
		Sole Slurry	11.34 ± 2.04 [b]	17.19 ± 2.82 [b]	21.05 ± 2.56 [b]	24.75 ± 1.80 [b]	27.78 ± 1.20 [b]	31.29 ± 1.51 [b]	33.34 ± 1.50 [c]
		Sole Fertilizer	10.81 ± 2.47 [b]	15.82 ± 2.07 [c]	21.06 ± 1.42 [b]	25.10 ± 1.10 [b]	28.13 ± 1.16 [b]	31.96 ± 1.29 [b]	35.23 ± 1.12 [b]
		Control	7.95 ± 2.20 [c]	11.63 ± 2.12 [d]	15.09 ± 3.47 [c]	18.39 ± 4.04 [c]	21.64 ± 4.13 [c]	24.78 ± 4.78 [c]	28.43 ± 5.11 [d]
		Summary of analyses of variance (p values)							
		Treatment (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		Ward (W)	<0.001	0.151	0.119	0.011	<0.001	0.009	0.014
		T × W	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means bearing distinct alphabet letters (for every season and down the column) vary significantly at $p \leq 0.05$ by the LSD test.

Table 5. Number of leaves per plant (means ± standard error) at Werugha and Wusi-Kishamba wards from sprouting (week 1) to maturity (week 7) as influenced by treatments in the 2020 short rains and 2021 long rains seasons.

Season	Ward	Treatment	Number of Leaves per Plant						
			Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
2020 Short rains	Werugha	Bioslurry + Fertilizer	9.23 ± 2.50 [a]	11.45 ± 1.65 [a]	13.28 ± 0.85 [a]	14.15 ± 0.86 [a]	15.15 ± 0.77 [a]	16.10 ± 0.90 [a]	17.80 ± 1.51 [a]
		Sole Slurry	7.40 ± 1.52 [b]	9.23 ± 0.80 [c]	10.85 ± 1.05 [c]	11.55 ± 0.93 [c]	12.78 ± 0.97 [c]	13.78 ± 1.29 [c]	14.53 ± 1.40 [c]
		Sole Fertilizer	7.98 ± 1.35 [b]	10.00 ± 0.85 [b]	11.88 ± 0.69 [b]	13.30 ± 0.82 [b]	14.23 ± 1.23 [b]	14.88 ± 1.57 [b]	15.45 ± 1.88 [b]
		Control	4.25 ± 1.33 [c]	6.80 ± 1.64 [d]	10.15 ± 1.05 [c]	10.68 ± 1.21 [d]	12.00 ± 0.85 [d]	13.50 ± 0.99 [c]	14.18 ± 1.36 [c]
	Wusi-Kishamba	Bioslurry + Fertilizer	7.13 ± 2.47 [a]	9.73 ± 1.72 [a]	13.28 ± 0.88 [a]	14.33 ± 0.94 [a]	15.10 ± 1.03 [a]	15.83 ± 1.47 [a]	17.40 ± 2.17 [a]
		Sole Slurry	5.83 ± 2.11 [b]	8.00 ± 1.26 [c]	9.75 ± 1.60 [c]	10.93 ± 1.00 [c]	12.33 ± 1.05 [c]	13.03 ± 1.48 [c]	13.98 ± 1.61 [c]
		Sole Fertilizer	6.58 ± 1.65 [a]	8.73 ± 1.55 [b]	10.83 ± 1.68 [b]	12.58 ± 0.93 [b]	13.38 ± 1.25 [b]	14.35 ± 1.58 [b]	15.15 ± 1.83 [b]
		Control	4.15 ± 1.33 [c]	6.10 ± 1.46 [d]	9.03 ± 1.85 [d]	9.80 ± 1.11 [d]	11.23 ± 1.31 [d]	12.93 ± 1.12 [c]	13.20 ± 1.30 [d]
2021 Long rains	Werugha	Bioslurry + Fertilizer	7.13 ± 2.47 [a]	9.73 ± 1.72 [a]	13.28 ± 0.88 [a]	14.33 ± 0.94 [a]	15.10 ± 1.03 [a]	15.83 ± 1.47 [a]	17.40 ± 2.17 [a]
		Sole Slurry	5.83 ± 2.11 [b]	8.00 ± 1.26 [c]	9.75 ± 1.60 [c]	10.93 ± 1.00 [c]	12.33 ± 1.05 [c]	13.03 ± 1.48 [c]	13.98 ± 1.61 [c]
		Sole Fertilizer	6.58 ± 1.65 [a]	8.73 ± 1.55 [b]	10.83 ± 1.68 [b]	12.58 ± 0.93 [b]	13.38 ± 1.25 [b]	14.35 ± 1.58 [b]	15.15 ± 1.83 [b]
		Control	4.15 ± 1.33 [c]	6.10 ± 1.46 [c]	9.03 ± 1.85 [c]	9.80 ± 1.11 [c]	11.23 ± 1.31 [c]	12.93 ± 1.12 [c]	13.20 ± 1.30 [d]
	Wusi-Kishamba	Bioslurry + Fertilizer	9.20 ± 2.52 [a]	11.63 ± 1.37 [a]	12.85 ± 0.66 [a]	14.05 ± 0.71 [a]	15.00 ± 0.60 [a]	15.90 ± 0.81 [a]	17.25 ± 1.19 [a]
		Sole Slurry	7.43 ± 1.47 [b]	8.80 ± 1.22 [c]	10.28 ± 0.93 [c]	11.60 ± 0.78 [c]	12.40 ± 0.87 [c]	13.23 ± 1.07 [c]	14.20 ± 1.11 [c]
		Sole Fertilizer	7.98 ± 1.37 [b]	9.93 ± 0.89 [b]	11.65 ± 0.80 [b]	13.00 ± 0.85 [b]	13.70 ± 1.16 [b]	14.63 ± 1.44 [b]	15.25 ± 1.77 [b]
		Control	3.88 ± 0.94 [c]	6.38 ± 1.46 [d]	9.48 ± 0.85 [d]	10.85 ± 1.14 [d]	12.13 ± 0.76 [c]	12.95 ± 0.85 [c]	13.65 ± 1.27 [d]
		Summary of analyses of variance (p values)							
		Treatment (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		Ward (W)	0.739	0.400	0.007	0.767	0.116	0.024	0.065
		T × W	0.953	0.731	0.817	0.697	0.428	0.824	0.930

Means bearing distinct letters down the column (per season) vary significantly at $p \leq 0.05$ by LSD.

Table 6. Tuber yield indices (means ± standard error) at Werugha and Wusi-Kishamba wards as influenced by treatments in the 2020 short rains and 2021 long rains seasons.

Season	Ward	Treatment	Marketable Tuber Yield (t ha^{-1})	Unmarketable Tuber Yield (t ha^{-1})	Total Tuber Yield (t ha^{-1})	Marketable Tuber Number per Plant^{-1}	Unmarketable Tuber Number per Plant^{-1}	Total Tuber Number per Plant^{-1}
2020 Short rains	Werugha	Bioslurry + Fertilizer	15.67 ± 2.09 ^{a}	4.00 ± 0.27 ^{c}	19.67 ± 2.24 ^{a}	6.75 ± 0.96 ^{a}	0.75 ± 0.50 ^{c}	7.50 ± 1.29 ^{a}
		Sole slurry	9.42 ± 2.11 ^{b}	6.08 ± 0.50 ^{b}	15.50 ± 2.08 ^{c}	3.75 ± 0.50 ^{bc}	2.75 ± 0.50 ^{b}	6.50 ± 1.00 ^{a}
		Sole fertilizer	11.83 ± 2.35 ^{b}	5.25 ± 0.32 ^{bc}	17.08 ± 2.39 ^{b}	5.50 ± 0.58 ^{ab}	2.00 ± 0.82 ^{bc}	7.50 ± 1.29 ^{a}
		Control	4.38 ± 0.67 ^{c}	8.38 ± 1.46 ^{a}	12.75 ± 1.61 ^{d}	2.00 ± 1.15 ^{c}	6.25 ± 0.96 ^{a}	8.25 ± 1.71 ^{a}
	Wusi-Kishamba	Bioslurry + Fertilizer	15.58 ± 0.92 ^{a}	3.92 ± 0.79 ^{c}	19.50 ± 0.64 ^{a}	7.75 ± 0.50 ^{a}	1.00 ± 0.82 ^{c}	8.75 ± 0.96 ^{ab}
		Sole slurry	9.08 ± 0.92 ^{c}	6.54 ± 0.57 ^{b}	15.63 ± 1.09 ^{c}	3.75 ± 0.50 ^{c}	3.00 ± 0.82 ^{b}	6.75 ± 1.26 ^{c}
		Sole fertilizer	11.42 ± 0.79 ^{b}	5.50 ± 0.19 ^{bc}	16.92 ± 0.96 ^{b}	5.50 ± 1.00 ^{b}	2.50 ± 0.58 ^{b}	8.00 ± 0.82 ^{b}
		Control	4.33 ± 0.72 ^{d}	8.50 ± 1.37 ^{a}	12.83 ± 0.79 ^{d}	2.25 ± 0.50 ^{c}	6.75 ± 0.50 ^{a}	9.00 ± 0.82 ^{a}
2021 Long rains	Werugha	Bioslurry + Fertilizer	23.67 ± 2.02 ^{a}	5.00 ± 1.09 ^{c}	28.67 ± 2.02 ^{a}	8.25 ± 0.50 ^{a}	0.00 ± 0.00 ^{c}	8.25 ± 0.50 ^{a}
		Sole slurry	11.42 ± 1.81 ^{c}	8.42 ± 1.26 ^{ab}	19.83 ± 2.78 ^{b}	4.00 ± 0.00 ^{c}	2.75 ± 0.50 ^{b}	6.75 ± 0.50 ^{b}
		Sole fertilizer	15.08 ± 0.92 ^{b}	6.58 ± 0.69 ^{bc}	21.67 ± 1.36 ^{b}	6.00 ± 0.00 ^{b}	2.25 ± 0.50 ^{b}	8.25 ± 0.05 ^{a}
		Control	5.25 ± 1.69 ^{d}	10.00 ± 1.09 ^{a}	15.25 ± 1.40 ^{c}	2.50 ± 0.58 ^{d}	6.75 ± 0.50 ^{a}	9.25 ± 0.05 ^{a}
	Wusi-Kishamba	Bioslurry + Fertilizer	21.00 ± 1.28 ^{a}	4.50 ± 1.29 ^{c}	25.50 ± 2.53 ^{a}	7.75 ± 0.96 ^{a}	1.50 ± 0.58 ^{b}	9.25 ± 0.96 ^{a}
		Sole slurry	9.92 ± 2.64 ^{bc}	6.17 ± 0.79 ^{bc}	16.08 ± 2.50 ^{b}	4.75 ± 0.96 ^{b}	3.25 ± 0.50 ^{b}	8.00 ± 1.15 ^{a}
		Sole fertilizer	12.00 ± 1.41 ^{b}	7.21 ± 1.07 ^{b}	19.21 ± 1.71 ^{b}	5.75 ± 0.96 ^{b}	2.50 ± 1.00 ^{b}	8.25 ± 0.96 ^{a}
		Control	5.92 ± 0.74 ^{c}	9.92 ± 1.97 ^{a}	15.83 ± 2.63 ^{b}	1.75 ± 1.26 ^{c}	7.75 ± 1.50 ^{a}	9.50 ± 1.91 ^{a}
		Summary of analyses of variance (p values)						
		Treatment (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		Ward (W)	0.011	0.496	0.016	0.099	0.003	0.002
		Season (S)	<0.001	<0.001	<0.001	<0.001	0.882	<0.001
		T × W	0.191	0.352	0.312	0.286	0.002	0.008
		T × S	<0.001	<0.001	<0.001	<0.001	0.685	<0.001

Means bearing distinct alphabet letters (for every season and down the column) vary significantly at $p \leq 0.05$ by LSD test3.3.2. Marketable, unmarketable, and total tuber yield.

4. Discussion

4.1. Effect of Combined Bioslurry and DAP Fertilizer on Potato Growth Parameters

This study revealed a high response of potato plant growth indices to the combined use of bioslurry and synthetic fertilizer (DAP). This could be attributed to the certainty that plants readily extracted essential nutrients (NPK) promptly, which boosted plant growth, increased root length, and therefore resulted in increased plant height. The relationship demonstrated by the use of synthetic fertilizer (DAP) on plant growth aligns with observations made by Cicek et al. [29] and Hudai et al. [30] that the use of phosphatic-based fertilizers increases plant height, root diameter, and basal stem diameter of potatoes. Adequate nutrient supply was noted to trigger a significant increase in plant height with the combined application of 200 kg ha^{-1} of DAP with bioslurry, which also stimulated good growth and development of potato roots as well as adequate uptake of other vital plant nutrients [4,31].

An optimal supply of nutrients to plants helps to improve soil physicochemical and biological properties, thereby supplying crops with the required amounts of nutrients [6]. This corresponds with the results obtained by Surindra [32]. Furthermore, Sarwar et al. [33] and Alhammad et al. [34] observed that plant height increase was also attributed to bioslurry fertilizer, which probably contains various essential macro- and micronutrients that are needed for the healthy growth of plants. Slurry compost can provide the required nutrients to crops, thus improving soil fertility, which boosts the general growth performance and health of crops.

Surindra [32] and Kisaka et al. [35] observed that organic soil amendments compensate for less and excess soil nutrients. Similar findings were made by Gonzalez et al. [36], who found that both slurry and chemical fertilizer provided essential nutrients that are essential for enhanced plant height. Substantiating the findings of this experiment, Shadrack et al. [37] also reported that stem elongation is a result of plant height increases due to fertilizer use. Similarly, the results of this study agreed with Nazir's [38] findings on strawberry plants grown using combined wet slurry and phosphate fertilizer. Mirzapour et al. [39] reported that such observations might be attributed to the sufficient soil supply of plant nutrients in balanced amounts from both slurry and synthetic fertilizer, which enhanced lateral shoot growth of the potato crop. Also, with good uptake of soil nutrients by crop plants, there was enhanced vegetative growth.

The observed increase in height of the plants was also chalked up to a sufficient supply of plant nutrients in the root zone, which enhanced good absorption and utilization for better crop growth. The dominance observed with the combined application of slurry and DAP fertilizer in comparison with the control treatment can be associated with the direct fostering of root development [40]. Another possible explanation is the production of fixed nutrients which led to nutrients, being available around the plant roots, hence nurturing crop growth and development [41]. These observations might also be attributed to the adequate soil supply of plant nutrients in balanced amounts from both slurry and synthetic fertilizer, which enhanced the lateral shoot growth of the potato crop. Also, good absorption of soil nutrients by crop plants enhanced vegetative growth [41].

In conclusion, predominance was noted in the treatment with the combined application of DAP fertilizer and bioslurry, which might also be related to improved root development and growth [4]. In addition, the let-out of riveted plant nutrients, thereby surging the rate of absorbed nutrients in the root's rhizosphere, could have increased potato plant growth and development [37].

4.2. Effect of Combined Bioslurry and DAP Fertilizer on Potato Yield

A combined application rate of DAP and slurry resulted in an increased marketable tuber number per plant compared to the control treatment. Also, DAP fertilizer provided phosphorus to plants in good quantities, which significantly increased the marketable tuber number per plant. Increased N uptake from bioslurry constituents accounted for a low number of unmarketable tubers because of the increased weight of individual tubers. In line with the findings of this study, Shangguan et al. [40] observed an increase in marketable tubers following a combined application of DAP and bioslurry.

The increment of the unmarketable tuber number per plant in the control plot was attributed to inadequate plant nutrient supply in the soil as compared to other plots, which led to reduced tuber size and weight, hence being unmarketable. A marked reduction in unmarketable tuber numbers per plant (2) was also observed in fertilizer treatment, which was attributed to an increased level of phosphorus supply to plants [41–43]. This in turn increased the aboveground biomass through photosynthesis and net assimilation processes, resulting in increased tuber weight and size, so the tuber could be categorized as marketable [11].

With regards to the total tuber number plant^{-1}, the observations made were credited to the residual remains of plant nutrients, particularly from bioslurry components in the first season, which sustained photosynthetic active leaves for a longer time as compared to control [33]. Due to phosphorus's immobility in the soil, its application during the plant growth period is of the essence [2,4]. Studies have reported that phosphorus influences not only the tuber yield but also its size distribution [37,41]. Tuber yield was also noted to be influenced by the mutual application of bioslurry and DAP fertilizer through the provision of critical nutrients (such as K, P, and N), which resulted in an enhanced number of tubers per plant [27].

The highest marketable tuber yield noted from the synergistic use of slurry + DAP showed that the combined application of chemical fertilizer with organic manure promoted not only good vegetative growth with increased leaf area but also photosynthetic ability [44–46]. This resulted in the production of larger tubers from healthy plants, resulting in an increased marketable yield. Marketable tuber yield is a representative valuation of potato crop productivity. The interaction of slurry and fertilizer resulted in a significant effect on marketable tuber yield, and a remarkable contrast was also observed among other treatments. This is attributed to the main impact of essential nutrient availability in adequate quantities (NPK), which was made available to plants. Agreeing with these findings, Zelalem et al. [27] observed that the phosphorus in DAP and slurry was released to plants in high quantities, which led to increased marketable tuber yield. This finding also supports an earlier publication by Araujo et al. [21], where it is documented that not only total tuber yield but also the quantity of marketable tuber yield appreciably improves with the use of slurry and fertilizer.

In addition, the observed variation in unmarketable tuber yield that was detected in the control plot was attributed to the inadequate nutrient level available or supplied in the soil. This resulted in plants being susceptible to pest and disease attacks and therefore ending up producing very small-sized tubers, hence the low yield. Application of chemical fertilizer (DAP) in combination with bioslurry reduced unmarketable tubers when compared to control as well as other treatments. Tubers grouped as unmarketable were due to cracking, pest and disease damage, and very small-sized tubers of less than 28 mm gauge. This was evident in control, sole slurry, and sole fertilizer treatments, and their numbers were reduced with increased application of macronutrients. This study recommends that unmarketable tubers can not only be reduced through manipulation of pest and disease incidences and increased recommended application rates of plant nutrients in required quantities, but also through all the necessary agronomic practices to warrant high crop productivity [36,47,48].

The significant increase in total tuber yield in the long rains season was attributed to residual nutrients in the soil after the short rains season harvest and additional application of slurry and fertilizer, which signified adequate nutrient supply to plants in the two wards (Werugha and Wusi-Kishamba). Similarly, in line with the findings of this study, Eleiwa et al. [49] together with Mulubrhan [50] observed that the use of slurry and DAP fertilizer provided phosphorus in the right quantities, hence leading to increased tuber yield. In addition, Eleiwa et al. [49] noted that slurry provided significant amounts of essential (NPK) nutrients, which contributed to a high potato total tuber yield at harvest. Mulubrhan [50] reported that the application of DAP and slurry provided phosphorus, which is an essential nutrient that significantly contributed to the improvement in total potato yield.

5. Conclusions and Recommendation

The study indicated significant responses in potato growth and yield parameters with the use of bioslurry in conjunction with inorganic fertilizer compared to sole fertilizer application. Hence, the synergistic application of bioslurry and synthetic fertilizer (DAP) is recommended for optimum potato growth and yield. Therefore, the study recommends capacity building to ensure satisfactory knowledge of bioslurry use and its adoption by potato growers for soil fertility management and enhanced crop productivity. More study is also of essence to look at other potato quality variables, such as tuber size and weight, that were not captured in the current study.

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References

1. Rykaczewska, K. The impact of high temperature during the growing season on potato cultivars with different responses to environmental stresses. *Am. J. Plant Sci.* **2013**, *4*, 2386–2393. [CrossRef]
2. Li, M.; Zhang, H.; Yang, X.; Ge, M.; Ma, Q.; Wei, H.; Dai, Q.; Huo, Z.; Xu, K.; Luo, D. Accumulation and utilization of nitrogen, phosphorus and potassium of irrigated rice cultivars with high productivities and high N use efficiencies. *Field Crops Res.* **2014**, *161*, 55–63. [CrossRef]
3. Aragaw, M.; Abebe, T.; Amare, T.; Worku, W. Phosphorous use efficiency of widely grown potato (*Solanum tuberosum* L.) varieties in Ethiopia. *Turkish J. Agric. Food Sci. Tech.* **2022**, *10*, 2001–2009. [CrossRef]
4. Kamau, S.; Karanja, N.N.; Gachene, C.K.K.; Gitari, H.I.; Sharma, K.; Schulte-Geldermann, E. Nitrogen and phosphorous uptake by potato (*Solanum tuberosum* L.) and their use efficiency under potato-legume intercropping systems. *Field Crops Res.* **2018**, *222*, 78–84. [CrossRef]
5. Mwakidoshi, E.R.; Gitari, H.I.; Muindi, E.M. Economic Importance, Ecological Requirements, Production Constraints of Potato (*Solanum tuberosum* L.) in Kenya. *Int. J. Biores. Sci.* **2021**, *8*, 61–68. [CrossRef]
6. Chappa, L.R.; Mugwe, J.; Gitari, H.H.; Maitra, S. Upholding sunflower (*Helianthus annuus*) yield and profitability while maintaining soil fertility under intercropping with sunn hemp and mineral fertilizer application. *Int. J. Biores. Sci.* **2023**, *10*, 31–49. [CrossRef]
7. Danga, B.; Otieno, M.A.; Gitari, H.I.; Karuma, A.N. Soil properties and fertility management with respect to Capsicum (*Capsicum annuum* L.) production in Nairobi Peri-urban Counties. *J. Soil Sci. Plant Nutr.* **2021**, *22*, 374–392. [CrossRef]
8. Hassan, M.J.; Raza, M.A.; Rehman, S.U.; Ansar, M.; Khan, I.; Wajid, M.; Ahmed, M.; Shah, G.A.; Gitari, H.I.; Peng, Y.; et al. Effect of cadmium toxicity on growth, oxidative damage, antioxidant defense system and cadmium accumulation in two sorghum cultivars. *Plants* **2020**, *9*, 1575. [CrossRef] [PubMed]
9. Sairaam, M.; Maitra, S.; Praharaj, S.; Nath, S.; Shankar, T.; Sahoo, U.; Santosh, D.T.; Sagar, L.; Panda, M.; Priya, G.S.; et al. An Insight into the Consequences of Emerging Contaminants in Soil and Water and Plant Responses. In *Emerging Contaminants and Plants*; Aftab, T., Ed.; Springer: Cham, Switzerland, 2023. [CrossRef]

10. Brestic, M.; Maitra, S.; Hossain, A.; Skalicky, M.; Gitari, H.I.; Brahmachari, K.; Shankar, T.; Bhadra, P.; Palai, J.B.; Jena, J.; et al. Intercropping system—A low input agricultural strategy for food and environmental security. *Agronomy* **2010**, *11*, 343. [CrossRef]
11. Alhammad, B.A.; Roy, D.K.; Ranjan, S.; Padhan, S.R.; Sow, S.; Nath, D.; Seleiman, M.F.; Gitari, H. Conservation tillage and weed management influencing weed dynamics, crop performance, soil properties, and profitability in rice-wheat-greengram system in Eastern Indo-Gangetic Plains. *Agronomy* **2023**, *13*, 1953. [CrossRef]
12. Nyawade, S.O.; Karanja, N.N.; Gachene, C.K.K.; Gitari, H.I.; Schulte-Geldermann, E.; Parker, M.L. Short-term dynamics of soil organic matter fractions and microbial activity in smallholder legume intercropping systems. *Appl. Soil Ecol.* **2019**, *142*, 123–135. [CrossRef]
13. Haverkort, A.J.; van Koesveld, M.J.; Schepers, H.T.A.M.; Wijnands, J.H.M.; Wustman, R.; Zhang, X. *Potato Prospects for Ethiopia: On the Road to Value Addition*; PPO-AGV: Lelystad, The Netherlands, 2012.
14. Tesfaye, A.; Lemaga, B.; Mwakasendo, J.A.; Nzohabonayoz, Z.; Mutware, J.; Wanda, K.Y.; Kinaye, P.M.; Ortiz, O.; Crissman, C.; Thiele, G. *Markets for Fresh and Frozen Potato Chips in the ASARECA Region and the Potential for Regional Trade: Ethiopia, Tanzania, Rwanda, Kenya, Burundi and Uganda*; Working Paper No. 2010-1; International Potato Center (CIP): Lima, Peru, 2010.
15. Ochieng, I.O.; Gitari, H.I.; Mochoge, B.; Rezaei-Chiyaneh, E.; Gweyi-Onyango, J.P. Optimizing maize yield, nitrogen efficacy, and grain protein content under different N forms and rates. *J. Soil Sci. Plant Nutr.* **2021**, *21*, 1867–1880. [CrossRef]
16. Tuncturk, R.; Rahimi, A.; Lyons, G.; Heydarzadeh, S.; Tuncturk, M. Effects of Vermicompost.; Compost and Animal Manure on Vegetative Growth, Physiological and Antioxidant Activity Characteristics of *Thymus vulgaris* L. under Water Stress. *Yuz. Yil Univ. J. Agric. Sci.* **2023**, *32*, 40–53. [CrossRef]
17. Dittert, K.; Karanja, N.N.; Gachene, C.K.; Mugo, J.N.; Gitari, H.I.; Schulte-Geldermann, E. Response of potato crop to selected nutrients in Central and Eastern highlands of Kenya. *Cogent Food Agric.* **2021**, *7*, 1898762. [CrossRef]
18. Warnars, P. From Biomass to Biogas: Present Day Status and Future Requirements. Master's Thesis, Utrecht University, Utrecht, The Netherlands, 2013.
19. GoK-Government of Kenya. *Agricultural Sector Development Support Program*; Ministry of Agriculture Livestock and Fisheries: Nairobi, Kenya, 2014.
20. MoALF–Ministry of Agriculture Livestock and Fisheries. *Irrigation Agronomy*, 4th ed.; Ministry of Agriculture Livestock and Fisheries: Nairobi, Kenya, 2020.
21. Araújo, T.H.; Pádua, J.G.; Spoto, M.H.; Ortiz, V.D.; Margossian, P.L.; Dias, C.T.; Melo, P.C. Productivity and quality of potato cultivars for processing as shoestrings and chips. *Hort. Bras.* **2016**, *34*, 554–560. [CrossRef]
22. Pansu, M.; Gautheyrou, J. Mineralogical, organic, and inorganic methods. In *Handbook of Soil Analysis*; Scrimgeour, C., Ed.; Springer: Berlin/Heidelberg, Germany; New York, NY, USA, 2007; Volume 43, p. 401. [CrossRef]
23. Ryan, J.; Garabet, S.; Rashid, A.; El, G.M. Assessment of soil and plant analysis laboratories in the West Asia-North Africa region. Soil and plant analysis laboratory manual. Beirut: ICARDA. *Commun. Soil Sci. Plant Anal.* **2007**, *30*, 885–894. [CrossRef]
24. Willis, R.B.; Montgomery, M.E.; Allen, P.R. Improved method for manual, colorimetric determination of Total Kjeldahl Nitrogen using Salicylate. *J. Agric. Food Chem.* **1996**, *44*, 1804–1807. [CrossRef]
25. Yeomans, J.C.; Bremner, J.M. A rapid and precise method for routine determination of organic carbon in the soil. *Commun. Soil Sci. Plant Anal.* **1988**, *19*, 1467–1476. [CrossRef]
26. Tekalign, T. Response of Potato to Paclobutrazol and Manipulation of Reproductive Growth under Tropical Conditions. Ph.D. Dissertation, University of Pretoria, Pretoria, South Africa, 2005.
27. Zelalem, A.; Tekalign, T.; Nigussie, D. Response of potato (*Solanum tuberosum* L.) to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia. *Afr. J. Plant Sci.* **2009**, *3*, 16–24.
28. Mohammed, B.; Martin, G.; Laila, M.K. Nutritive values of the drought tolerant food and fodder crop enset. *Afr. J. Agric. Res.* **2013**, *8*, 2326–2333. [CrossRef]
29. Cicek, E.; Yilmaz, F.; Yilmaz, M. Effect of N and NPK fertilizers on early field performance of narrow-leaved ash. *Fraxinusangustifolia. J. Environ. Biol.* **2010**, *31*, 109–114. [PubMed]
30. Hudai, S.M.S.; Sujauddin, M.; Shafinat, S.; Uddin, M.S. Effects of phosphorus and potassium addition on growth and nodulation of *Dalbergiasissoo* in the nursery. *J. For. Res.* **2007**, *18*, 279–282. [CrossRef]
31. Adhikari, C.R.; Sharma, D.M. Use of chemical fertilizers on potatoes in sandy loam soil under humid sub-Tropical conditions of Chitwan. *Nepal Agric. Res. J.* **2004**, *5*, 23–26.
32. Surindra, S. Impact of vermin-compost and composted farmyard manure on growth and yield of garlic (*Allium stivum* L.) field crop. *Int. J. Plant Prod.* **2009**, *3*, 27–38.
33. Sarwar, G.H.; Schmeisky, M.A.; Tahir, Y.; Iftikhar, S.N.U. Application of green compost for improvement in soil chemical properties and fertility status. *J. Anim. Plant Sci.* **2010**, *20*, 258–260.
34. Alhammad, B.A.; Mohamed, A.; Raza, M.A.; Ngie, M.; Maitra, S.; Seleiman, M.F.; Wasonga, D.O.; Gitari, H.I. Optimizing productivity of Buffel and Sudan grasses using optimal nitrogen fertilizer application under arid conditions. *Agronomy* **2023**, *13*, 2146. [CrossRef]
35. Kisaka, M.O.; Shisanya, C.; Cournac, L.; Manlay, J.R.; Gitari, H.I.; Muriuki, J. Integrating no-tillage with agroforestry augments soil quality indicators in Kenya's dry-land agroecosystems. *Soil Tillage Res.* **2023**, *227*, 105586. [CrossRef]
36. Gonzalez, C.I.; Bhattacharya, A.; Wang, W.; Peltz, S.W. Nonsense-mediated mRNA decay in *Saccharomyces cerevisiae*. *Gene* **2001**, *274*, 15–25. [CrossRef]

37. Gitari, H.I.; Shadrack, N.; Kamau, S.; Gachene, C.K.K.; Karanja, N.N.; Schulte-Geldermann, E. Agronomic assessment of phosphorus efficacy for potato (*Solanum tuberosum* L.) under legume intercrops. *J. Plant Nutr.* **2020**, *43*, 864–878. [CrossRef]
38. Nazir, N. Effect of integrated organic nutrient management on fruit yield and quality of strawberry Senga. *Int. J. Farm. Sci.* **2015**, *5*, 83–89.
39. Heydarzadeh, S.; Arena, C.; Vitale, E.; Rahimi, A.; Mirzapour, M.; Nasar, J.; Kisaka, O.; Shivan, S.; Ranjan, S.; Gitari, H. Impact of different fertilizer sources under supplemental irrigation and rain-fed conditions on eco-physiological responses and yield characteristics of dragon's head (*Lallemantia iberica*). *Plants* **2023**, *12*, 1693. [CrossRef] [PubMed]
40. Shangguan, Z.; Shao, M.; Dyckmans, J. Effects of nitrogen nutrition and water deficit on net photosynthetic rate and chlorophyll fluorescence in winter wheat. *J. Plant Physiol.* **2000**, *156*, 46–51. [CrossRef]
41. Zhao, C.J.; Nasar, J.; Khan, R.; Gul, H.; Gitari, H.I.; Shao, Z.; Abbas, G.; Haider, I.; Iqbal, Z.; Ahmed, W.; et al. Maize-soybean intercropping at optimal N fertilization increases the N uptake, N yield and N use efficiency of maize crop by regulating the N assimilatory enzymes. *Front. Plant Sci.* **2023**, *13*, 1077948. [CrossRef]
42. Sanderson, J.B.; MacLeod, J.A.; Douglas, B.; Coffin, R.; Bruulsema, T. Phosphorus research on potato in PEI. In Proceedings of the XXVI International Horticultural Congress: Potatoes, Healthy Food for Humanity: International Developments in Breeding, Toronto, ON, Canada, 11–17 August 2002; Volume 619, pp. 409–417.
43. Muindi, E.M.; Muindi, C.M.; Ndiso, J. The effects of combining farm yard manure, starter nitrogen, phosphorus, and zinc on growth and yield of green grams. *J. Agric. Ecol. Res. Int.* **2020**, *20*, 1–9. [CrossRef]
44. Raza, M.A.; Gul, H.; Wang, J.; Yasin, H.S.; Qin, R.; Khalid, M.H.B.; Naeem, M.; Feng, L.Y.; Iqbal, N.; Gitari, H.; et al. Land productivity and water use efficiency of maize-soybean strip intercropping systems in semi-arid areas: A case study in Punjab Province. *Pak. J. Clean. Prod.* **2021**, *308*, 127282. [CrossRef]
45. Nasar, J.; Wang, G.Y.; Zhou, F.J.; Zhou, X.B.; Gitari, H.I.; Tabl, K.M.; Hasan, M.E.; Ali, H.; Waqas, M.M.; Ali, I.; et al. Nitrogen fertilization coupled with foliar application of iron and molybdenum improves shade tolerance of soybean under maize soybean intercropping. *Front. Plant Sci.* **2022**, *13*, 1014640. [CrossRef] [PubMed]
46. Boguszewska-Mańkowska, D.; Pieczyński, M.; Wyrzykowska, A.; Kalaji, H.M.; Sieczko, L.; Szweykowska-Kulińska, Z.; Zagdańska, B. Divergent strategies displayed by potato (*Solanum tuberosum* L.) cultivars to cope with soil drought. *J. Agron. Crop Sci.* **2017**, *204*, 13–30. [CrossRef]
47. Gitari, H.I.; Gachene, C.K.K.; Karanja, N.N.; Kamau, S.; Nyawade, S.; Sharma, K.; Schulte-Geldermann, E. Optimizing yield and economic returns of rain-fed potato (*Solanum tuberosum* L.) through water conservation under potato-legume intercropping systems. *Agric. Water Manag.* **2018**, *208*, 59–66. [CrossRef]
48. Yasin, H.S.; Gul, H.; Qin, R.; Din, A.M.U.; Khalid, M.H.B.; Hussain, S.; Saeed, A.; Wang, J.; Rezaei-Chiyaneh, E.; Sabagh, A.E.; et al. Maize/soybean strip intercropping produces higher crop yields and saves water under semi-arid conditions. Front. *Plant Sci.* **2022**, *13*, 1006720. [CrossRef]
49. Eleiwa, E.M.; Ibrahim, S.A.; Mohamed, F.M. The combined effect of NPK levels and foliar nutritional compounds on growth and yield parameters of potato plants (*Solanum tuberosum* L.). *Afr. J. Microbiol. Res.* **2012**, *6*, 5100–5109.
50. Mulubrhan, H. The Effect of Nitrogen, Phosphorus, and Potassium Fertilization on the Yield and Yield Components of Potato (*Solanum tuberosum* L.) Grown on Vertisols of the Mekele Area. Master's Thesis, Haramaya University, Dire Dawa, Ethiopia, 2004; pp. 22–54.