Effects of Intercropping Sweetpotato (*Ipomea. Batatas*) With Pigeonpea on Productivity and Major Pest of Sweetpotato in Malawi

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Citation: Longwe K, Akiniwale G, Mwenye J.O, Van Vugt D, Chiipanthenga M, Phiri T.A. (2023) Effects of Intercropping Sweetpotato (*Ipomea. Batatas*) With Pigeonpea on Productivity and Major Pest of Sweetpotato in Malawi. FARA Research Report *Vol 7(62):800-809*. https://doi.org/10.59101/frr072362

Abstract:

Intercropping sweet potato and pigeonpea can improve sweetpotato productivity in Malawi. The study investigated the effects of sweetpotato-pigeonpea intercrop on sweetpotato yield and weevil incidence. The study was conducted over two years during 2020-2021 and 2021/22 cropping seasons at Baka, Kandiyani and Chitala. Five treatments were cropping systems; Sole sweetpotato, sweetpotato+pigeonpea strip cropped; 1:1 (SP+PP-2:1) and 2:1 (SP+PP-2:1) and within-row intercrop (SP+PP-within-row) were laid out in Randomized Complete Block Design (RCBD) replicated three times. Yield data and pest's incidence were collected at two harvesting intervals: 5 and 6 months allowing more exposure to sweetpotato weevil. Data was subjected to analysis of variance using R Programming. In the 2020/21, the highest yields of sweetpotato were recorded sole crop at Baka (14.3 t/ha) and Chitedze (22 t/ha) while it did not differ from SP+PP-2:1 (17 t/ha). Partial land equivalent ratio (pLER) for sweetpotato was greater than 0.5 in all treatments at Chitala and Chitedze, except for Baka. The incidence of Sweet Potato Weevil was found to be significantly lower in intercropped systems compared to sole cropped systems. SP+PP-row recorded zero weevil incidence at Baka and lowest, 2.8% at Chitala during second harvesting in 2020/21 while SP+PP-2:1 strikingly reduced weevil incidence by 5% at second harvesting. In 2021/22, SP+PP-1:1 and SP-PP-row both led to reduction of the incidences by 11.4% and 18.1% percent respectively The results suggest that the intercroping system can be a viable strategy for improving sweet potato productivity, especially in areas with similar soil and environmental conditions.

Keywords: Intercrop, Sweetpotato, Yield, Sweetpotato weevil, incidence

1. Introduction

In Malawi, sweetpotato is ranked as the second most important root crop for food security after cassava, and it is becoming an increasingly important cash crop for many households. Orange fleshed sweetpotato (OFSP) varieties are highly nutritious due to their rich content of beta-carotenes, which are essential in combating malnutrition, particularly in children [1]. However, despite its importance, farmers in Malawi are currently experiencing low yields of between 5 to 10 tons per hectare (T/ha) [2], whereas improved varieties have the potential to produce up to 25 to 35 T/ha. Some of the main factors that lead to low crop yields are poor agronomic practices, limited availability of quality planting materials, declining soil fertility and pest and disease problems.

Climate-smart agriculture offers various options for increasing sweet potato productivity and overcoming constraints faced by smallholder farmers, with legume intensification being one of them due to their ability to fix nitrogen and provide multiple agroecological benefits [3]. However, in Malawi, the integration of legumes in sweet potato farming systems has not been extensively researched compared to cereal systems. Although a few studies have been conducted, such as the one by Abidin et al. [4], which showed that intercropping sweet potato with soybean in a one to three repeating planting patterns along the ridge resulted in high productivity among the sweet potato-soybean intercrop options. Other studies have focused on tillage systems in sweet potato rotational studies with soybean and pigeonpea. Although sweet potato and pigeonpea are being intercropped by some farmers in southern Malawi, there is no established system or planting pattern being used.

Pigeonpea is a highly suitable crop for intercropping with sweet potato due to several characteristics that it possesses. Firstly, it has a slow above-ground growth rate in the initial stages of growth, which means that it does not compete with sweet potato for sunlight and other resources. Additionally, its upright canopy structure and deep taproot make it compatible for intercropping with low-growing crops like sweet potato, as it reduces competition both above and below ground [5]. Among the grain legume crops, pigeonpea produces a high amount of biomass and is able to fix nitrogen in the soil. The amount of nitrogen fixed has been reported to range between 11 to 86 kg Nha^{-1} in sole crop and about 28 kg nitrogen per hectare ($kgNha^{-1}$) in maize relay intercrop [7]. The deep taproot system of pigeonpea also allows it to access nutrients and minerals from deeper soil horizons, which benefits the accompanying crop in an intercrop [8]. Pigeonpea is a multipurpose crop, with its stem being used as firewood. It is also rich in protein, with levels ranging from 18-25%, making it an excellent source of nutrition for humans and animals [9]. These qualities make pigeonpea an ideal companion crop for intensifying smallholder sweet potato production in maize-dominated systems. It can increase soil fertility and productivity while also diversifying the diet of smallholder farmers. Overall, the intercropping of sweet potato and pigeonpea is a sustainable and beneficial agricultural practice that can contribute to the long-term success of smallholder farming systems.

The aim of this research was to examine how various intercropping methods between sweet potato and pigeonpea could impact the productivity of sweet potato, as well as the incidence of sweet potato weevils, which are a significant economic pest for sweet potato.

2. Materials and Methods

2.1. Site

The study was conducted for two years during 2020-2021 and 2021/22 cropping seasons. On-station experiments were established at three research stations namely Baka, Chitala and Chitedze representing two main agroecological zones in Malawi, the low and mid altitude [10]. Baka is in karonga, 09°54' S, 33°56'E, lakeshore AEZ and has a mean annual rainfall of 1070 mm. Chitala is located 30km west of Salima town. It is in a semi-arid region in lowlands and lakeshore AEZ, 13.25°S, 34.30°E and 606 m.a.s.l and receives a mean of 1170 mm of rainfall per annum. Predominant soils are sandy clay-loam soils. At Chitedze the study was implemented at Kandiyani substation that is in Lilongwe, 13°55’ S and 33°39’E, in the mid altitude zone and receives 900 mm annual rainfall.

2.2. Treatment Combination and Experimental design

Orange Fleshed Sweetpotato (OFSP) was intercropped with Pigeonpea in strip crop and within row. Strip crops were arranged in 1:1 and 2:1 alternate ridgeS with sweetpotato as a principal crop. Treatments were basically cropping systems as follows:

i. Sole sweetpotato (Sole SP)
ii. Sole pigeonpea (Sole PP)
iii. Sweetpotato + pigeon pea – Within row (SP+PP-Row)
iv. Sweetpotato + pigeon pea – 1:1 alternate row (SP+PP-1:1)
v. Sweetpotato + pigeon pea – 2:1 alternate row (SP+PP-2:1)

The experiment was laid out in Randomized Complete Block Design (RCBD) replicated three times.

2.3. Field establishment and maintenance

Plots dimensions comprised of 8 ridges that were 5 m long spaced at 75 cm. spacing for the crops varied depending on the planting arrangements.

Sweetpotato was planted at uniform plant stations spacing of 30 cm in all the treatments using 30 cm length vine cuttings. The variety used kadyaubwelere, is mid maturing that takes about 4 months and widely preferred by farmers. Weeding was done once at as soon as weeds appear followed with hilling at least twice before maturity. Pigeonpea, spacings differed between alternate and within row intercropping. Two plants per station were planted at 50 cm spacing in alternate ridges and sole stand while a wider spacing of 100 cm was used for within row intercrop, leaving 15 cm space to sweetpotato crop. The variety used Chitedze 1, a short maturing variety.

2.4 Soil Sampling and laboratory analysis

Soil samples for physical and chemical analysis were collected at 0-20 cm and 20-40 cm depth with the aid of soil auger. Soil Textural Class was analyzed by the Dispersal Method, pH was determined using pH meter in water by following [11] procedure, total soil nitrogen (N) was determined using the micro-Kjeldhal method [12], Soil organic carbon (SOC) by the procedure of Walkley-Black wet oxidation method. Mehlich 3 extracting solution procedure was used in the determination of extractable phosphorus (P) and potassium (K).

2.5 Data Collection

Stand Count; **n**umber of plants fully sprouted were counted 2 weeks after planting and at harvesting, number of harvested plants were recorded. Vines was uprooted from the net plot, tied in heap, and weighed to determine vine yield. All plants in the net plot were harvested, grading the roots into two categories small, of not suitable market quality weight less than 100g and big, weighing more than 100g that with market quality. Each grade was then counted and weighed, a proportion of marketable root yield and total root yield determined. All data was extrapolated to a hectare. Vines and all harvested roots were assessed for sweetpotato weevil damage, all damaged roots were counted and expressed as a percentage and for statistical comparisons, percent wilted plants were transformed into square roots before analysis.

2.6. Partial Land Equivalent Ratio

Partial Land Equivalent Ratio (PLER) values was calculated to determine the contribution of sweetpotato, being the principal crop of interest to determine its contribution towards total LER and provides an indication of the efficiency of sweetpotato in intercropping systems [13]. The LER is generally used to assess the land use advantage of intercropping [14] and basically estimates area under sole cropping that will be required to produce same amount of yield as one unit area to crops under intercropping. An LER of value of greater than1 indicates a yield advantage for intercrop per unit land area while in this study, pLER value of 0.5 was used as benchmark to determine intercrop interference on sweetpotato where any greater than 0.5 that legumes intercrop had no negative effects on sweetpotato yield compared to monoculture [15].

The formula for calculating an LER is:

$$LER = pLERs + pLERr$$

Where $pLER_S$ and $pLER_L$ are partial LER for sweetpotato and legumes respectively and LERs calculated as the yield of sweetpotato in intercrop (Yis) divided by the yield of sweetpotato in sole crop (Yss):

$$pLERs = \frac{Yis}{Yss}$$

2.7. Data analysis

Data handling and exploratory data analysis were achieved in excel while statistical analyses and charts were performed using R Programming 4.0.3 [16]. Growth and yield data parameters were subjected to analysis of variance (ANOVA). The differences between the means were determined using least significant difference (LSD) at $P < 0.05$ probability.

3. Results

3.1. Soil Data

Table 1 presents the physical and chemical characteristics of the soil across the three research sites. The soils were generally acidic, with varying degrees of acidity, and most were deficient in nitrogen, phosphorus, and potassium as compared to the critical values established by Snapp [17] and ratings by Chilimba [18]. A pH level below 5.2 is considered acidic, and soil organic carbon (SOC), nitrogen (N), phosphorus (P), and potassium (K) levels below 0.8%, 0.1%, 13 mgkg-1, and 0.2 Cmol/Kg respectively, are considered insufficient for healthy plant growth [17]. At Baka, nitrogen and potassium levels were limited, with concentrations below the critical value, while topsoil phosphorus and organic carbon were in medium quantities above the critical level. The topsoil at Baka was slightly acidic, while the subsoil was acidic. Likewise, at Chitala, both topsoil and subsoil were acidic, with organic carbon percentage slightly above the critical value and low levels of phosphorus and potassium. At Chitedze, the soils were moderately acidic, with pH levels above the critical value for both topsoil and subsoil. Organic carbon, nitrogen, and calcium levels were all above their critical values, except for phosphorus and potassium, which were below critical levels. The soils at Chitedze were classified as sandy loamy. Potassium is the most crucial nutrient element required for sweetpotato in terms of nutrient uptake per unit area and root yield. However, it is important to maintain a balance for all other nutrient elements [19].. Therefore, the low levels of potassium at all sites might negatively affect sweetpotato yields.

Table 1. Levels *of key* soil properties for the experimental fields for at different research stations. Critical soil test values used; pH =5.2, OC =0.8%; N = 0.1%, P mg kg-1, K = 0.2 Cmol/Kg, CA 0.2 Cmol/Kg *[17]*

Properties	Depth	Site			Critical Value
		Baka	Chitala	Chitedze	
	0-20	6.1	5.3	5.7	5.2
pH	20-40	5.8	5.4	6.1	
	0-20	1.1	1.0	1.8	0.8
% OC	20-40	0.6	1.0	1.6	
	0-20	0.1	0.1	0.2	0.1
%N	20-40	0.1	0.1	0.1	
	0-20	27.3	1.8	3.3	13
P (ug/g)	20-40	14.0	0.8	1.3	
	0-20	0.0	0.1	0.0	0.2
K (Cmol/Kg)	20-40	0.1	0.1	0.0	
	0-21	0.9	0.8	0.5	0.2
Ca (Cmol/Kg)	20-41	1.0	1.0	0.6	
	0-22	7.0	26.2	12.5	
% Clay	20-42	9.0	24.2	10.5	
	0-23	18.0	8.0	12.0	
% Silt	20-43	14.0	8.0	10.0	
	0-20	Loamy Sand	Sandy Clay Loam	Sandy Loam	
Tex. Class	20-40	Sandy Loam	Sandy Clay Loam	Sandy Loam	

3.2. Stand Count at physiological maturity

The results of plant density for sweetpotato in different intercrop arrangements with pigeonpea at physiological maturity are presented in Figure 1. At the Baka, there was no interaction between cropping systems and season in terms of stand count ($p = 0.6$), and the stand count did not differ significantly among the cropping systems ($p = 0.18$). However, season had a significant effect on plant population, with the highest stand count of 23889 plants/ha observed in the 2021/22 season ($p = 0.01$).

At the Chitedze site, there was also no interaction between cropping systems and season (p = 0.07), but sweetpotato stand count was significantly affected by cropping system (p = 0.006), with the highest population obtained in sole sweetpotato, 30,556 plants/ha across seasons. Season also had a significant effect on stand count (p < 0.001), with the highest stand count of 33,889 plants per ha recorded in 2021. At the Chitala site, there was an interaction between cropping system and season in terms of stand count (p = 0.003), with the highest population recorded in sole sweetpotato, 40,000 plants/ha in 2020/21, while the lowest was recorded in the SP+PP-1:1 intercrop arrangement, 16,111 plants per ha in 2021/22.

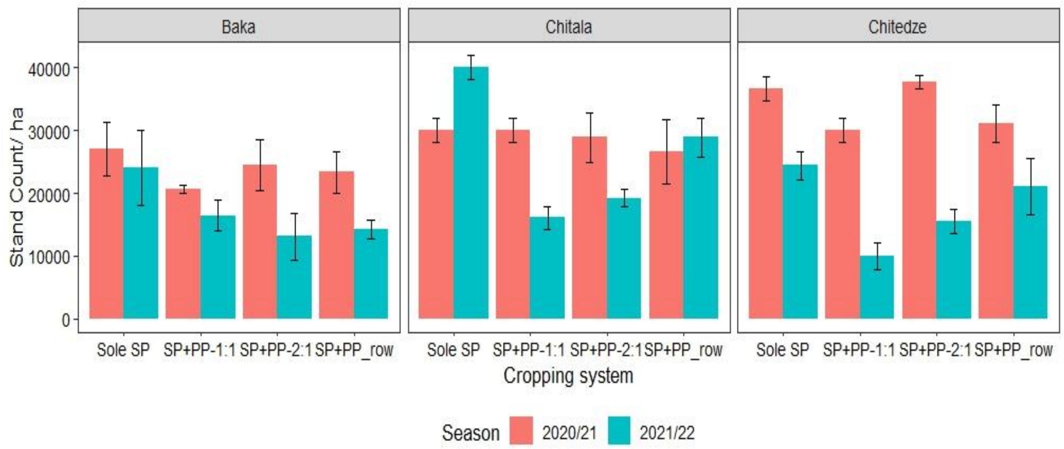

Figure 1. Plant population of sweetpotato plants in different intercrop arrangement with Pigeonpea at physiological maturity at Baka, Chitala and Chitedze. *Sweetpotato yield, yield component and productivity*

Table 2 presents the results of the study on the effects of different intercrop options on sweetpotato vine yield, marketable root yield, and total root yield. At Baka, sweetpotato vine yield varied significantly among the cropping systems in the 2021/22 season (p=0.02), with the highest yield obtained in the sole crop system at 26.6 T/ha, followed by SP+PP-2:1 at 21 T/ha, and the lowest yield recorded in within-row SP+PP_row at 4.7 T/ha. Sweetpotato total root yield (p=0.03) and marketable root yield (p<0.03) also differed significantly among cropping systems in the 2020/21 season, with the highest yields obtained in the sole crop system at 25.4 T/ha and 13.2 T/ha, respectively. In the 2021/22 season, the sole crop system recorded the highest total root yield at 26.9 T/ha (p<0.001) and marketable root yield at 26.6 T/ha (p<0.001). However, there were no significant differences in total root yield and marketable root yield among the intercrop options in both seasons. At Chitala and Kandiyani, intercropping with pigeonpea did not have any significant effect on sweetpotato vine yield, marketable root yield, and total root yield across two seasons, as shown in Table 2.

Table 2. Effect of pigeonpea intercrop options on sweetpotato vine yield (**VY (T/ha)**), marketable root yield (**MRY (T/ha)**) and total root yield (**TRY (T/ha)**) at various sites across two seasons

Season (A)	**Cropping system (B)**	**Baka**			**Chitala**			**Chitedze**		
		VY	**MRY**	**TRY**	**VY**	**MRY**	**TRY**	**VY**	**MRY**	**TRY**
2020/21	Sole SP	15.3	13.2[a]	14.3[a]	4.7	8.5	9.7	2.9	18.4	22
	SP+PP_row	9.0	6.1[b]	7[b]	4.4	5.8	6.5	2.0	10.9	14.5
	SP+PP-1:1	8.6	6.1[b]	7.7[b]	4.1	3.3	3.8	5.0	13.2	14.9
	SP+PP-2:1	8.7	9.5[ab]	10.9[ab]	3.9	8.6	9.5	4.2	14.4	17.0
	CV %	35	60	62	38	72	69	34	22	25
	Fpr	0.5	0.02	0.03	0.9	0.5	0.4	0.05	0.1	0.1

2021/22	Sole SP	26.6[a]	26.9[a]	29.3[a]	14.3	6.0	6.9	16.2	14.1	16.5
	SP+PP_row	4.7[c]	0.6[b]	0.7[b]	9.4	2.2	2.6	10.1	7.9	8.9
	SP+PP-1:1	11.6[bc]	1.6[b]	2[b]	9.5	2.4	2.5	8.1	11.5	12.4
	SP+PP-2:1	21.9[ab]	5.4[b]	6[b]	17.9	7.0	7.4	9.6	8.0	9.2
	CV %	44	54	55	66	51	77	60	66	63
	Fpr	0.02	<0.001	<0.001	0.5	0.3	0.2	0.4	0.6	0.5
AxB	Fpr	0.07	0.6	0.5	0.6	0.9	0.6	0.3	0.8	0.9

1. * Number in a column followed by similar superscript letters are not statically different

The partial LER for sweetpotato total root yield showed variability across different study sites and seasons, as illustrated in Figure 2. In the case of Baka, the PLER for sweetpotato was greatly reduced, with none of the intercrops exceeding 0.5 in both the 2020/21 and 2021/22 seasons. However, at Chitala and Chitedze, all intercrops with pigeonpea achieved a PLER greater than 0.5 in the 2020/21 cropping season. In the 2021/2022 season, at Chitedze, SP+PP_row recorded a PLER of 0.5, while SP+PP-1:1 and SP+PP-2:1 achieved a PLER greater than 0.5. At Chitala, only SP+PP-2:1 achieved a PLER greater than 0.5.

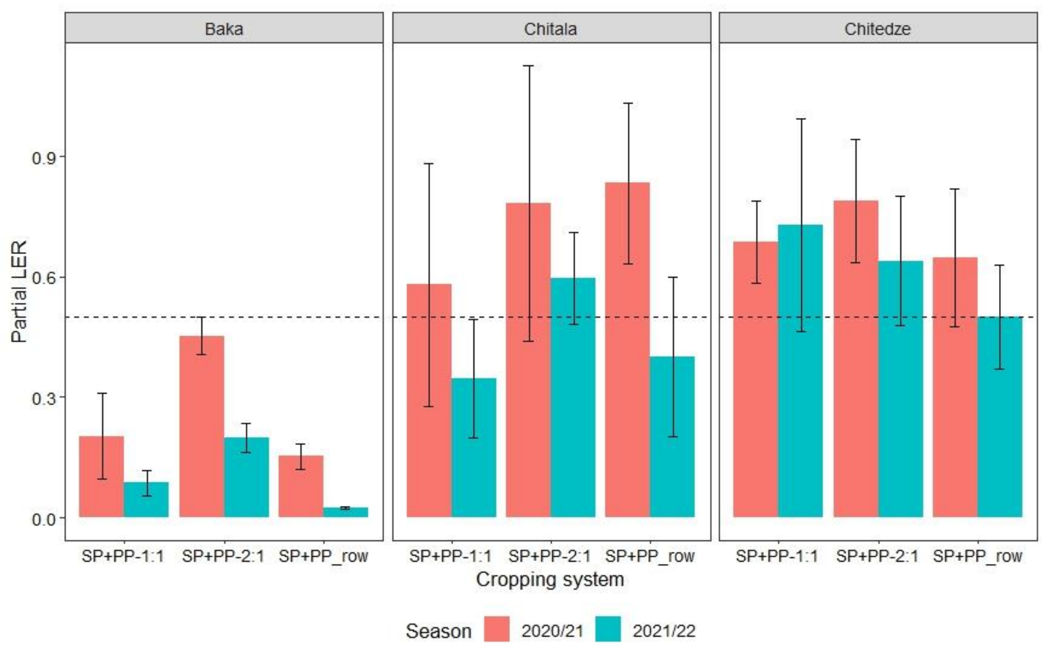

Figure 2. Partial LER for sweetpotato root yield intercropped with different pigeonpea options at various sites

3.3. Sweetpotato weevil incidences

The incidences of sweetpotato weevils varied across different sites, seasons, and time of harvesting, and was significantly impacted by the cropping systems (Figures 3 and 4).

In the 2020/21 season at Baka, all cropping systems had no weevil incidence during the first harvesting, but weevil incidence significantly increased to 20.6% in sole SP during the second harvesting ($p < 0.001$), while SP+PP-1:1 and SP+PP-row had no weevil incidence. In 2021/22, all intercrops were free from weevil incidence, while sole crop had 7% weevil incidence during the first harvesting and rose to 25% during the second harvesting, with lower increases in SP+PP-1:1 and SP+PP-2:1 and no weevil incidence in SP+PP-row.

At Chitala, during the 2020/21 season, weevil incidence was zero at first harvesting for sole SP and SP+PP-row, while sole SP significantly increased to 12.1% ($p = 0.02$), and SP+PP-row significantly reduced weevil incidence to 2.8% during the second harvest ($p = 0.04$). SP+PP-2:1 recorded the highest weevil incidence of 23.6% during the first harvesting but significantly reduced to 19.6% during the second harvesting. In 2021/22, weevil incidences were lower compared to 2020/21, and most treatments showed a tendency to maintain lower incidences, except for sole SP, which recorded a significant increase from 4 to 13% during the second harvesting (Figure 4).

At Chitedze, there were no weevil incidences during both harvesting intervals in all cropping systems during the 2020/21 season. However, during the 2021/22 season, sole SP had the highest incidences during the first harvest, 43.7%, which rose to 48.4% during the second harvesting. SP+PP-1:1 and SP-PP-row reduced the incidences over time by 11.4% and 18.1%, respectively (Figure 4).

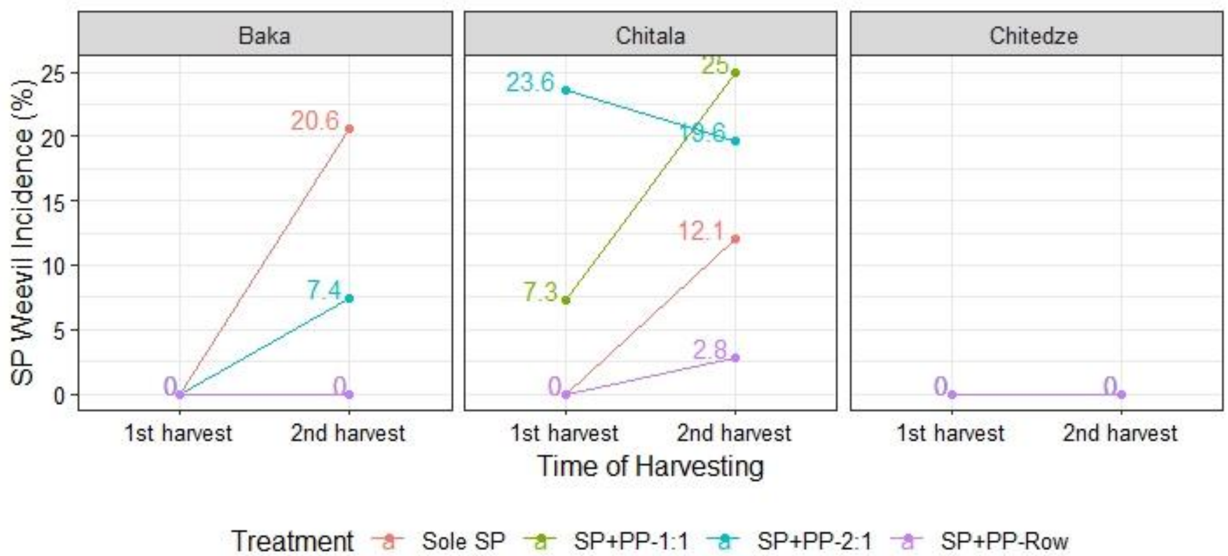

Figure 3. Effects of cropping system on sweetpotato weevil incidence at difference harvesting time in 2020/21 cropping season

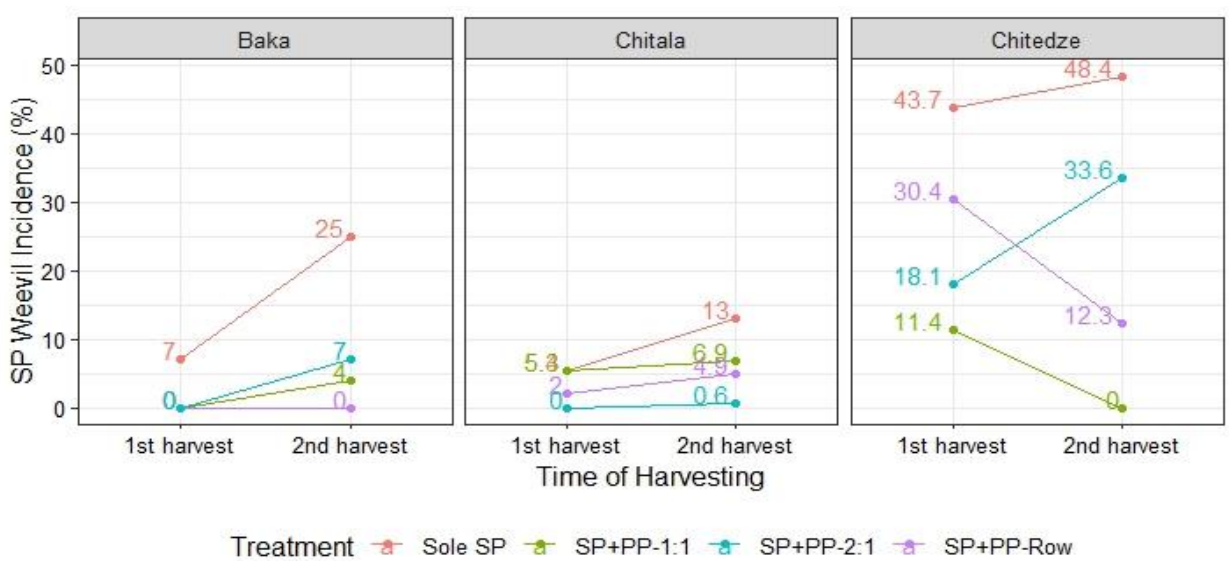

Figure 4. Effects of cropping system on sweetpotato weevil incidence at difference harvesting time in 2021/22 cropping season

4. Discussion

The findings of this study have revealed some important aspects regarding the intercropping of sweet potato and pigeonpea, which has been identified as a potential strategy to increase the productivity of sweet potato in Malawi. The results from the analysis of soil data across the three research sites revealed that the soils were generally acidic and deficient in nitrogen, phosphorus, and potassium which supports existing evidence that soils in Malawi are largely poor and declining in fertility [20, 21]. The low levels of potassium at all sites might negatively affect sweet potato yields, although the positive organic carbon and nitrogen levels at some sites could potentially offset this. Therefore, soil management practices such as the addition of fertilizer, compost and organic matter could be used to improve soil fertility and sweet potato yields.

The prevailing sweetpotato production practice in Malawi is characterized by cultivating the crop in marginal fields with zero application of fertiliser. The increasing unaffordability of inorganic fertiliser [22] will further discourage farmers to invest in inorganic fertiliser as a source of the needed crop nutrients the phenomenon that will lead to farther nutrient mining, soil degradation and reduction in crop productivity. It in this context that we have explore opportunities for improving nutrient supply to sweetpotato through intercropping with grain legumes due to their ability to fix nitrogen [22].

The study observed differences in the initial plant population of sweetpotato among different intercrop options at Chitedze and Chitala, but interestingly, no such differences were observed at Baka. This could be attributed to the high number of crop deaths in the sole crop due to a dry spell that occurred in both seasons, leading to a similar stand count among cropping systems at Baka. While the initial high population in the sole crop could have resulted in higher yields, this was not the case at Chitala and Chitedze, where vine and root yields did not differ among the cropping systems over two seasons. This could be due to the compensatory yield tendency of crops in crop mixtures, which is a desirable attribute for sustainable intensification of sweetpotato cropping systems [23]. However, Baka exhibited vigorous growth for most crops which resulted in vigorous pigeonpea that choked and shaded sweetpotato in almost all intercrops compared to other sites. This could explain the observed yield differences. To mitigate this effect, it is recommended to change spacing to wider spacing at sites that lead to vigorous pigeonpea growth. In summary, the study's findings suggest that intercropping sweetpotato with grain legumes can improve nutrient supply and lead to compensatory yield tendencies that promote sustainable intensification of sweetpotato cropping systems.

The diminished PLER of sweetpotato at Baka is likely an effect of the affected sweetpotato yield in intercrop options as explained above. However, this did not much affect the resulting LER that was compensated by the high yield from pigeonpea which led to LER of greater than 1 in strip crops (SP+PP-1:1 and SP+PP:2:1) except in within-row intercrop (SP+PP-row) in both seasons. Apart from Baka, in 2020/21 season all intercrops at Chitala and Chitedze had PLER for sweetpotato greater than 0.5 which is likely indicator of the crop compatibility in intercrop with pigeonpea as suitable sustainable intensification option [24].

The incidence of sweet potato weevils was found to be significantly lower in intercropping systems compared to sole cropping systems, with the highest reduction in the within-row intercop system. This result suggests that intercropping could be a potential strategy for controlling sweet potato weevils, which are a significant economic pest for sweet potato. The lower incidence of sweet potato weevils in intercropping systems could be due to the masking effect of pigeonpea, which makes it difficult for the weevils to locate and lay eggs on the sweet potato plant. Additionally, pigeonpea has been shown to have allelopathic effects on other plants, which could potentially discourage the weevils from attacking sweet potato plants in intercropping systems [25]. However, there is also a tradeoff between incidence reduction and yield in the fact that within row intercropping of sweetpotato with pigeonpea was highly effective at reducing sweetpotato weevil incidence but led yield of sweetpotato and PLER was reduced. This may require further exploring the suitable spacing of pigeonpea in within-row spacing for optimum results.

5. Conclusion

Overall, the results of this study suggest that intercropping sweet potato and pigeonpea could be a sustainable and beneficial agricultural practice that can contribute to the long-term success of smallholder farming systems in Malawi. The intercropping system not only reduces the incidence of sweet potato weevils but also has the potential to increase soil fertility and productivity while also diversifying the diet of smallholder farmers. The study recommends the adoption of intercropping as a viable strategy for improving sweet potato productivity, especially in areas with similar soil and environmental conditions. However, further research is needed to evaluate the effects of intercropping on other yield components of sweet potato and pigeonpea and the economic viability of the system.Further studies recommended to explore suitable spacing of pigeonpea in within-row spacing for optimum results. Also recommended to qualify mechanisms for pigeonpea on reducing sweetpotato weevil incidence. Effects on soil fertility also needs to be quantified and adaptation at farmers field conditions.

Funding

This research was funded by European Union (EU) for under the DeSIRA programme.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Acknowledgments

We appreciate the support given by research station managers, scientists and technicians at Chitedze, Bvumbwe, Lunyangwa and Bembeke.

Conflicts of Interest

The authors declare no conflict of interest.

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