



ENHANCING THE PRODUCTIVITY OF MAIZE-BASED SYSTEMS IN DROUGHT-PRONE AREAS OF MALAWI THROUGH MAIZE-SWEETPOTATO INTERCROPPING

DEC
2024

Kareem Longwe, Elish Munda, Felistus
Chipungu, Rudo Mello Kapezi, Francis
Kuweruza, Wellington Jogo

Enhancing the Productivity of Maize-Based Systems in Drought-Prone Areas of Malawi through Maize-Sweetpotato Intercropping

**Kareem Longwe, Eliah Munda, Felistus Chipungu, Rudo Mello Kapezi,
Francis Kuweruza, Wellington Jogo**

December 2024

Enhancing the Productivity of Maize-Based Systems in Drought-Prone Areas of Malawi through Maize-Sweetpotato Intercropping.

© International Potato Center 2024

DOI: 10.4160/cip.2025.01.003

CIP publications contribute important development information to the public arena. Readers are encouraged to quote or reproduce material from them in their own publications. As copyright holder CIP requests acknowledgement and a copy of the publication where the citation or material appears. Please send a copy to the Communications Department at the address below.

International Potato Center

P.O. Box 1558, Lima 12, Peru

cip@cgiar.org • www.cipotato.org

Citation:

Longwe, K.; Munda, E.; Chipungu, F.; Mello Kapezi, R.; Kuweruza, F.; Jogo, W. *Enhancing the Productivity of Maize-Based Systems in Drought-Prone Areas of Malawi through Maize-Sweetpotato Intercropping*. International Potato Center. 21 p.

DOI: 10.4160/cip.2025.01.003

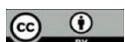
Corresponding author: E.Munda@cgiar.org

Design and Layout:

Communications Department

December 2024

CIP also thanks all donors and organizations that globally support its work through their contributions to the CGIAR Trust Fund: www.cgiar.org/funders



© 2024. This publication is copyrighted by the International Potato Center (CIP). It is licensed for use under the Creative Commons Attribution 4.0 International License

Contents

Abstract	5
1. Introduction.....	6
2. Materials and Methods	7
2.1 Site Description	7
2.2 Experimental design and treatments	8
2.3 Data Collection	10
3. Data Analysis	11
4. Results	12
4.1 Rainfall.....	12
4.2 Soil physical and chemical properties	12
4.3 Effect of sweetpotato-maize intercrop on Maize Yield and Harvest Index.....	13
4.4 Effect of sweetpotato-maize intercrop on sweetpotato root yield, biomass and Harvest index.....	13
4.5 The biological performance and economic efficiency of the intercropping systems	14
5. Discussion.....	17
6. Component crops yield under sole and intercrops	17
7. Resource Use Efficiency and Economic Viability	18
8. Challenges and Considerations for Adoption	18
9. Conclusion and Recommendations	19
10. Reference	20

Abstract

Maize is central to food security in Malawi, but its productivity is increasingly threatened by unpredictable rainfall, frequent droughts linked to climate change and high costs of inorganic fertilisers. Crop diversification through intercropping offers a promising strategy to enhance maize-based systems productivity and resilience to climate change. This study examined the productivity and resource use efficiency of maize-sweetpotato intercropping system in drought-prone areas in Malawi. The experiment evaluated strip intercropping arrangements against sole maize and sweetpotato at two sites in Utale and Masaula Extension Planning Areas (EPAs) in Balaka and Zomba Districts respectively during the 2023/2024 agricultural season which was characterized by low rainfall due to El Nino.

The results showed maize grain yield was significantly higher in sole maize (SM, 1.5 t/ha) than any of the intercropping arrangements ($p < 0.02$) while no significant differences ($p = 0.9$) were observed in harvest index across treatments. Sweetpotato yield was significantly affected by intercropping arrangements ($p < 0.001$), highest obtained in sole sweetpotato (SP, 14.2 t/ha) but did not differ with intercrops comprising of two ridges of maize at 50cm alternating with two ridges of sweetpotato at 100cm (T2, 13.1 t/ha), four ridges of maize at 50cm alternating with four ridges of sweetpotato at 100cm (T6, 13.1 t/ha), and four ridges of maize at 75cm alternating with four ridges of sweetpotato at 100cm (T8, 11.4 t/ha). Intercrops with two ridges of maize at 50cm alternating two ridges of sweetpotato at 75cm (T1), two ridges of maize at 50cm alternating with two ridges of sweetpotato at 100cm (T2), and four ridges of maize at 75cm alternating four ridges of sweetpotato at 100cm (T8) had land equivalent coefficient (LEC) > 0.25 and Land equivalent ratio (LER) > 1 at both sites indicating more efficient land use compared to monocropping. Sweetpotato contributed a greater proportion to the LER, and the positive correlation (R^2) between sweetpotato yield and sweetpotato equivalent yield (PEY) suggests its potential to enhance the economic efficiency of maize-based systems.

Maize-sweetpotato intercrops with two ridges of maize at 50cm alternating with two ridges of sweetpotato at 75cm (T1), two ridges of maize at 50cm alternating with two ridges of sweetpotato at 100 cm (T2), and four ridges of maize at 75cm alternating with four ridges of sweetpotato at 100cm (T8) are recommended for enhancing productivity and economic returns in drought-prone areas. Further research is needed to optimize plant density and spatial arrangement to maximize yields without sacrificing resource efficiency.

Keywords: Maize, Sweetpotato, Intercropping, Crop diversification, Adaptation

1. Introduction

Maize remains the cornerstone of food security in Malawi, serving as the primary staple crop for most households. In addition to cereal crops such as maize, Malawi produces other crops such as root and tuber crops and legumes. One of the most important commonly grown in Malawi is sweetpotato that is usually cultivated as sole crop. However, the growing unpredictability of rainfall patterns and the increasing frequency of droughts, exacerbated by climate change, have significantly undermined the productivity of sole maize-based systems, particularly in drought-prone areas (Stevens & Madani, 2016; Warnatzsch & Reay, 2020). A recent example is the 2023/2024 agriculture season that was negatively impacted by the El Niño weather phenomenon, which greatly disrupted crop production in Malawi and other southern African countries. The country experienced a delayed and erratic onset of effective rains for planting, inadequate total rainfall, fewer rainy days, and prolonged dry spells. These conditions severely affected crop production prospects, with maize, a staple crop registering a 16% decrease in yield (UN Malawi, 2024). This sharp decline contributed to heightened food insecurity. In addition to effects of climate change, Malawi soils have been severely degraded (FAO, 2018) such that crop production, especially maize requires inorganic fertilisers, whose costs have become unaffordable by many. Therefore, there is a need for strategies that can enhance the resilience and productivity of maize-based systems in the face of such climatic challenges.

Crop diversification has been put forward as a way to improve sustainable resilience of the maize dominated systems of smallholder farmers in the face of changing climate (Kumar et al., 2022). Intercropping maize with drought-tolerant crops such as sweetpotato offers a viable diversification approach to improving system productivity under these harsh conditions. Sweetpotato, especially resilient and nutrient dense varieties like orange-fleshed sweetpotato (OFSP), is well-suited for intercropping due to its ability to thrive in poor soils, its shorter growing period, and its capacity to withstand prolonged dry spells (Low et al., 2020). In addition to enhancing yield stability, sweetpotato provides a diverse nutritional profile, including high levels of vitamin A especially OFSP varieties, which is critical for addressing malnutrition in vulnerable communities (Gelaye, 2024; Girard et al., 2021).

Intercropping can significantly enhance productivity when compatible crops are carefully selected. However, the growth cycles of component crops need to be managed to avoid peak competition for resources. Effective intercropping involves planting component crops in ways that ensure their resource demands such as light, water, and nutrients do not coincide, optimizing the population densities of both crops. Maize and sweetpotato present a complementary growth habit that optimizes resource use. Maize, as a tall erect crop occupies the vertical space, while sweetpotato grows horizontally along the soil surface, with its creeping vines acting as a natural cover crop.

Research has shown that intercropping maize and sweetpotato increases overall productivity and improves resource use efficiency, particularly in terms of land utilization (Abidin et al., 2015; Katurumunda, 2021). In addition to enhancing yield, intercropping system has been reported to suppress weed growth (Nayan et al., 2020). However, other studies have noted potential drawbacks, including a decline in photosynthetically active radiation (PAR) reaching sweetpotato and a possible reduction in sweetpotato root yield within intercropping systems especially when the spatial arrangements is not carefully considered (Oswald et al., 1996; Yulong et al., 2017). Despite these challenges, the benefits of maize-sweetpotato intercropping, particularly in terms of overall system productivity and resource efficiency, make it a promising strategy for improving food security in drought-prone regions.

However, to date limited research has been carried evaluating to identify optimal intercropping arrangement of maize and sweetpotato and adaptive capacity of maize and sweetpotato intercrop under drought prone areas. This study investigates the potential of maize-sweetpotato intercropping as a strategy to improve the productivity of maize-based systems in drought-prone areas of Malawi. The research aims to assess the agronomic benefits and yield of maize and sweetpotato in an intercrop. Also to identify the optimal plant density and appropriate spatial arrangement for optimal yields. In addition, the study seeks to provide evidence for sustainable agricultural practices that can enhance productivity and resilience in the face of climate variability.

2. Materials and Methods

2.1 Site Description

On-farm trials were established in the semi-arid areas bordering two districts of Balaka and Zomba in southern Malawi region. The on-farm trials were established at two Agricultural Extension Planning Areas (EPAs), namely Masaula, located in Zomba, and Utale, located in Balaka (Fig. 1). The region falls within the tropical warm semi-arid agroecological zone (AEZ), characterized by a warm to hot climate, frequent and prolonged dry spells, with an average annual rainfall of less than 700 mm and an average annual temperature of 25°C (Chamasula & Rabumbulu, 2024).

The soils in the area are predominantly Cambisols, with some patches of Luvisols, both of which are suitable for a wide range of crop production (Zuza et al., 2022).

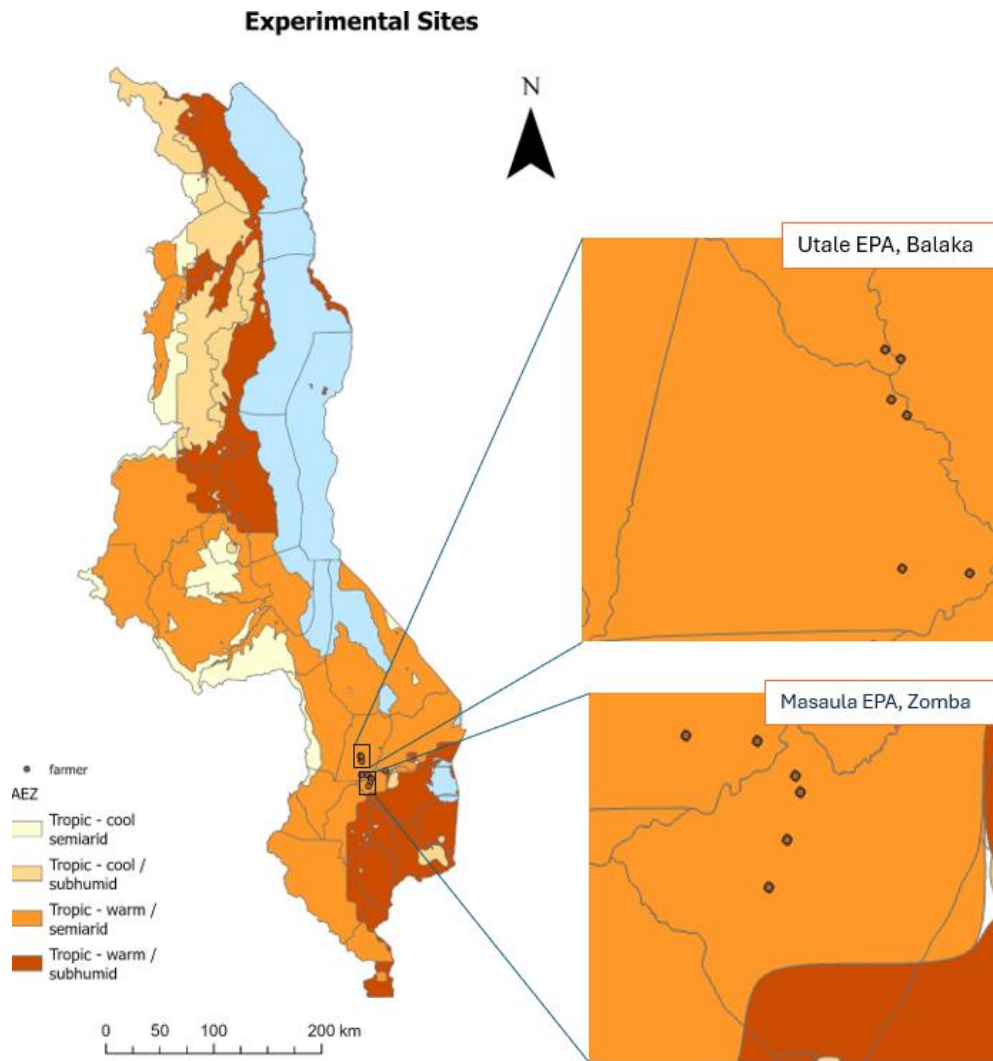


Figure 1. Map of Malawi pointing the sites of the field trials, categorised by the agroecological zones

2.2 Experimental design and treatments

The experiment was set up using a randomized complete block design (RCBD), with each farmer serving as a replicate within the Extension Planning Area (EPA). The trial was implemented across eight farmers' fields, with four fields located in each EPA.

The study evaluated different spatial intercropping arrangements of sweetpotato and maize using strip configurations with varying ridge numbers and spacings. The arrangements included:

- I. Alternating 2-Ridge Strip Arrangement: Two ridges of maize, spaced at either 50 cm or 75 cm, alternated with two ridges of sweetpotato, spaced at either 75 cm or 100 cm.
- II. Alternating 4-Ridge Strip Arrangement: Four ridges of maize, spaced at either 50 cm or 75 cm, alternated with four ridges of sweetpotato, spaced at either 75 cm or 100 cm.

These configurations together with pure stands for both crops resulted in ten (10) treatment combinations (Table 1, Figure 2). Each plot measured 100 m².

Sole crops of maize or sweetpotato were planted according to recommendations provided in the guide to agricultural production of Malawi (MoAIWD, 2021).

Table 1. Treatment and treatment description

Number	Treatment No.	Cropping Arrangement Description
1	SM	Pure stand maize, ridges at 75cm apart (recommended)
2	T1	Two ridges of maize at 50cm alternating two ridges of sweetpotato at 75cm
3	T2	Two ridges of maize at 50cm alternating two ridges of sweetpotato at 100cm
4	T3	Two ridges of maize at 75cm alternating two ridges of sweetpotato at 75cm
5	T4	Two ridges of maize at 75cm alternating two ridges of sweetpotato at 100cm
6	T5	Four ridges of maize at 50cm alternating four ridges of sweetpotato at 75cm
7	T6	Four ridges of maize at 50cm alternating four ridges of sweetpotato at 100cm
8	T7	Four ridges of maize at 75cm alternating four ridges of sweetpotato at 75cm
9	T8	Four ridges of maize at 75cm alternating four ridges of sweetpotato at 100cm
10	SP	Pure stand sweetpotato, ridges at 75cm apart (recommended)



Figure 2. Intercropping arrangement with four ridges of sweetpotato between four ridges of maize in the foreground, and two ridges of maize alternating with two ridges of sweetpotato in the background.

Soil sampling and analysis

Prior to establishing the field trials, soil samples were collected in November for laboratory analysis on soil health parameters to characterize the plots. Composite soil samples were collected from the farmers' fields at two depths: 0–20 cm and 20–40 cm for physical and chemical analysis. Using an auger, three individual samples were systematically collected in a diagonal line across the field, with two samples taken from each corner and one from the centre. The samples were then aggregated to form the composite samples. Soil textural class was analyzed by the dispersal method, pH was determined using pH meter in water (Wendt, 1996). Total soil nitrogen was determined using the kjeldahl method (Anderson & Ingram, 1993), soil organic carbon (SOC) by the procedure of Walkley-Black wet oxidation method (Bahadori & Tofighi, 2016). Mehlich 3 extracting solution procedure was used in the determination of extractable P, K and Ca (Ostatek-Boczynski & Lee-Steere, 2012). Values of the laboratory analysis were compared with established threshold values for Malawi soils to determine the soil status (Snapp, 1998).

Crop management

Planting

Planting was delayed due to a prolonged dry spell at the onset of the rainy season. Maize and sweetpotato were planted simultaneously in the first and second week of January 2024. The crop varieties that were used included a biofortified vitamin A-rich maize variety MH 43A, and an Orange-Fleshed Sweetpotato (OFSP) variety Kaphulira. Each farmer was provided with 12 bundles of Kaphulira cuttings.

Sweetpotato cuttings, each 30 cm long, were planted with a hill spacing of 30 cm, ensuring that two-thirds of each cutting was inserted into the soil. Maize was planted with a within-row hill spacing of 25 cm.

Weeding

Weeding was conducted twice during the growing season. The first weeding was carried out shortly after crop establishment to reduce competition from weeds. The second weeding was carried out during the vegetative stage, focused on hilling up the ridges, a practice commonly referred to as bunking.

Fertilizer Application

No fertilizer was applied to the sweetpotato crop. In maize, NPK fertilizer was applied at a rate of 200 kg/ha during planting. A top-dressing with urea at a rate of 150 kg/ha was planned for 21 days after planting. However, due to limited moisture availability, the top-dressing was delayed by 7 to 14 days, with the timing varying among farmers.

Harvesting

Maize got harvested after it reached physiological maturity at 130 days after planting and allowed to dry while sweetpotato was harvested at 150 days after planting.

2.3 Data Collection

Rainfall data was recorded using rain gauges installed in the farmers' fields and at the EPA offices. Yield and yield component data for both crops were collected at the net plot and extrapolated to a hectare.

Maize

Data collected included stand count at emergence and plant population at harvesting, total biomass, number of cobs per plant, cob weight, grain weight at harvesting. Maize stalks were cut, and 10 plants were randomly

selected for measurement. After removing the cobs from the stalks, the weight of the cobs before shelling and the grain weight after shelling were recorded.

Sweetpotato

Data collected included the number of plants at emergence and harvesting. Vine weight (kg), vines from the net plot were uprooted, tied into a heap, and weighed. The number and weight of marketable storage roots (those weighing 100g or more) and non-marketable roots (those weighing less than 100g) were also recorded per net plot.

Intercrop Performance

The biological performance of the intercropping systems was evaluated using the Land Equivalent Ratio (LER) and Land Equivalent Coefficient (LEC).

The LER is defined as the sum of the relative yields of intercropped species compared with their respective sole crops (Eq. 1) (Mead & Willey, 1980).

$$LER = \frac{Y_{pi}}{Y_{ps}} + \frac{Y_{mi}}{Y_{ms}}$$

Y_{pi} and Y_{mi} are the yields (per unit of total area of the intercrop) of species sweetpotato and maize in an intercrop, Y_{ps} and Y_{ms} are the yields of species 1 and 2 in the sole crops

Land equivalent coefficient (LEC)

$$A = (Y_{pi} * Y_{mi}) / (Y_{ps} * Y_{ms})$$

Y_{pi} and Y_{mi} depict the corresponding economic yield of sweetpotato and legume under the intercropping systems. In contrast, Y_{ps} and Y_{ms} represent the respective yields under pure stands.

If the values of (LEC) are higher than (0.25), it indicates that the Intercropping system has a crop advantage, and if it is less than that, it means that monoculture is the best and Intercropping cultivation is not capable of independently growing the available growth requirements in favour of the two Intercropping.

To determine the economic efficiency of intercropping systems sweetpotato equivalent yield (PEY) was calculated using (eq 3):

$$PEY = Y_{pi} + (Y_{mi} * P_m / P_p)$$

Where P_p and P_m represent the market prices of sweetpotato roots and maize grain respectively.

3. Data Analysis

Crop data and intercrop performance metrics were analyzed using a two-way analysis of variance (ANOVA) to evaluate the effects of site and cropping systems. Mean differences were determined using Fisher's Least Significant Difference (LSD) test at a significance level of $P < 0.05$. The analysis was conducted using the various package within R programming software, version 4.0.3 (Team R Core, 2020). Prior to statistical analysis, data normality was assessed using the Shapiro-Wilk test, where $p > 0.05$, data was considered to meet the normally assumption.

Rainfall charts were created using Microsoft Excel, while all other crop data visualizations were generated using the *ggplot2* package in R.

4. Results

4.1 Rainfall

The study sites experienced significantly reduced rainfall during the 2023/24 growing season due to the El Nino weather. At Masaula EPA, only 251 mm of rainfall was recorded, compared to 835 mm in the previous season. Rainfall commenced late in January and tapered off shortly after February (Figure 3a). Similarly, at Utale EPA, rainfall was also reduced, with 610 mm recorded compared to 968 mm in the previous year. The effective rainfall at Utale started late in January and extended into April (Figure 3b).

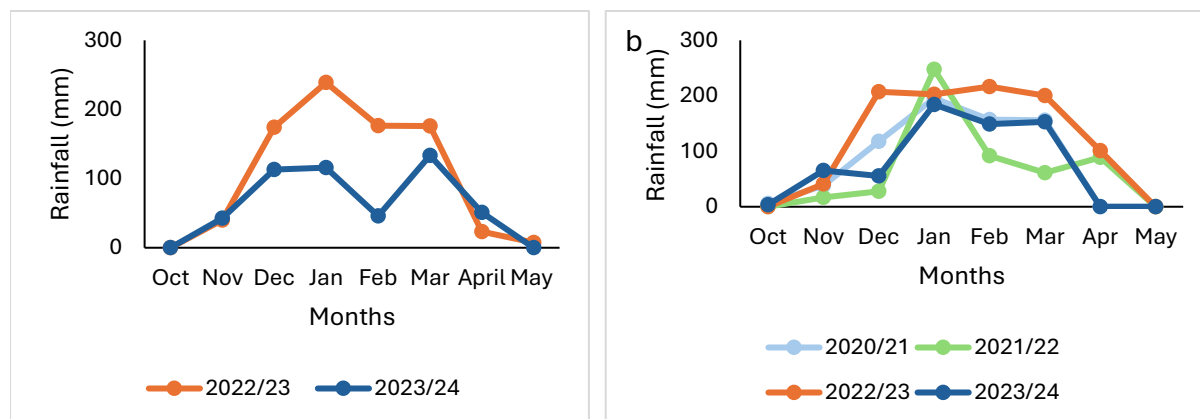


Figure 3. Rainfall (mm) received during the 2023/24 growing season at Masaula (a) and Utale (b) EPAs.

4.2 Soil physical and chemical properties

The soils at both sites are acidic, with low organic matter, total nitrogen, and potassium levels (Table 1). However, phosphorus, calcium, and magnesium levels were within adequate range, particularly at Utale.

Table 2. Physical and chemical properties of the soil from the farmers' fields at both sites.

Soil Property	Depth (cm)	Sites		Threshold value
		Masaula	Utale	
pH	0 - 20	5.3	5.9	
	20 - 40	5.5	5.8	5.2
OM (%)	0 - 20	0.4	0.5	
	20 - 40	0.4	0.6	1.4
Total N (%)	0 - 20	0.04	0.05	
	20 - 40	0.03	0.05	0.1
P (PPM)	0 - 20	26.6	53.3	
	20 - 40	14.7	48.2	13
k (cmol/kg)	0 - 20	0.1	0.2	

	20 - 40	0.1	0.1
CA (cmol/kg)	0 - 20	5.2	7.7
	20 - 40	5.9	9.6
Mg cmol/kg	0 - 20	0.7	1.0
	20 - 40	0.785	1.28
Texture	0 - 20	Sandy loam	Sandy loam

4.3 Effect of sweetpotato-maize intercrop on Maize Yield and Harvest Index

There was no significant interaction between sites and intercrop combinations for either maize yield or harvest index. However, maize grain yield varied significantly across the different cropping systems ($P = 0.02$). The highest maize yield of 1.5 tons per hectare (t/ha), was observed in the sole maize cropping system, which significantly outperformed all intercropping arrangement treatments. Among the arrangement treatments (T1 – T8), maize grain yields did not show statistical differences ($P = 0.02$) (Table 3).

Similarly, the harvest index did not vary significantly across the cropping systems ($P = 0.9$), with an average value of 34.4% across all cropping systems.

Table 3. Maize yield (kg/ha) and harvest index (%) from different cropping systems.

Cropping system	Grain Yield (t/ha)	Harvest index
Sole Maize	1.5 ^a	39.54
T7	0.77 ^b	37.26
T1	0.57 ^b	30.63
T5	0.66 ^b	32.40
T8	0.60 ^b	31.77
T3	0.72 ^b	31.01
T4	0.53 ^b	30.57
T2	0.77 ^b	39.56
T6	0.72 ^b	37.26
Mean		34.4
CV	59	
Pvalue	0.02	0.9

4.4 Effect of sweetpotato-maize intercrop on sweetpotato root yield, biomass and Harvest index

Table 4 presents the sweetpotato root yield, total biomass, and harvest index across different sweetpotato-maize intercropping arrangements and their respective pure stands. The results showed no interaction between intercrop arrangement and sites (EPA) ($p = 0.7$). However, there was significant differences in both sweetpotato root yield and total biomass among the cropping systems ($P < 0.001$) and between then sites, EPAs ($p = 0.004$)

Sole sweetpotato recorded the highest root yield at 14.2 t/ha, followed by intercropping system comprising of 2 ridges of maize at 50 cm alternating with 2 ridges of sweetpotato at 100 cm and 4 ridges of maize at 50 cm alternating with 4 ridges of sweetpotato at 100 cm, both yielding 13.1 t/ha. The lowest sweetpotato yields were observed in an intercropping system comprising of 2 ridges of maize at 75 cm alternating with 2 ridges of sweetpotato at 75 cm with 5.5 t/ha, and 4 ridges of maize at 75 cm alternating with 4 ridges of sweetpotato at 75 cm with 5.8 t/ha. Masaula recorded the highest sweetpotato mean root yield, 14.3 t/ha compared to 6.5 t/ha recorded in Utale.

Total biomass, the sole sweetpotato system achieved the highest value at 26.8 t/ha, significantly surpassing all other treatments. Among the intercropping arrangements, 2 ridges of maize at 50 cm alternating with 2 ridges of sweetpotato at 100 cm and 4 ridges of maize at 50cm alternating 4 ridges of sweetpotato at 100cm had the highest biomass values of 19.5 t/ha and 19.4 t/ha, respectively, while 4 ridges of maize at 75cm alternating 4 ridges of sweetpotato at 75cm intercropping arrangement recorded the lowest biomass at 11.9 t/ha.

The percentage of marketable roots did not vary significantly among treatments ($P = 0.51$) (Table 4). The sole sweetpotato treatment had the highest percentage of marketable roots at 82.0%, followed by an intercrop arrangement with 80.0%. The remaining intercropping treatments ranged between 61.8% and 74.8%.

Similarly, no statistically significant differences were observed in the harvest index among treatments ($P = 0.8$), with an overall average of 58.1%. The highest harvest index was recorded in 4 ridges of maize at 75 cm alternating with 4 ridges of sweetpotato at 75 cm intercropping treatment (66.2%), while the lowest harvesting index was observed in the intercropping treatment comprising of 2 ridges of maize at 75cm alternating 2 ridges of sweetpotato at 75cm (52.2%).

Table 4. Effect of sweetpotato-maize intercrop sweetpotato root yield, biomass and Harvest index

Cropping system	Yield (T/ha)	Total Biomass (T/ha)	Marketable Roots (%)	Harvest Index (%)
T1	9.3 ^{bc}	16.6 ^{b^c}	67.7	57.8
T2	13.1 ^{ab}	19.5 ^b	61.8	66.2
T3	5.5 ^e	12.8 ^{cd}	74.8	52.2
T4	7.0 ^{cd}	13.1 ^{cd}	70.6	52.5
T5	10.0 ^{bc}	16.4 ^{bc}	68.6	57.8
T6	13.1 ^{ab}	19.4 ^b	68.6	64.9
T7	5.8 ^{de}	11.9 ^d	80.0	53.2
T8	11.4 ^{ab}	18.4 ^b	71.5	58.0
SP	14.2 ^a	26.8 ^a	82.0	54.1
CV	26	17	20.0	31
P Value	<0.001	<0.001	0.51	0.8

4.5 The biological performance and economic efficiency of the intercropping systems

Figure 4 illustrates the partial land equivalent ratio (PLER) and total land equivalent ratio (LER) for maize and sweetpotato cropping systems. The results reveal no significant differences in PLER for maize, sweetpotato, or the total LER across the intercropping treatments. However, certain intercropping arrangements demonstrated more efficient land resource utilization.

Notably, intercrop arraignment treatments comprising 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 100cm (T2), 4 ridges of maize at 50cm alternating 4 ridges of sweetpotato at 75cm (T5), 4 ridges of maize at 50cm alternating 4 ridges of sweetpotato at 100cm (T6) and 4 ridges of maize at 75cm alternating 4 ridges of sweetpotato at 100cm (T8) achieved a PLER for sweetpotato greater than 1. This indicates that these systems produced more sweetpotato in the intercropping setup than in the sole cropping system, highlighting their superior land use efficiency.

Additionally, intercropping with 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 75cm (T1), 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 100cm (T2) and 4 ridges of maize at 75cm alternating 4 ridges of sweetpotato at 100cm (T8) recorded total LER values greater than 1 across both study sites, Masaula and Utale EPAs, emphasizing their potential to enhance land productivity compared to monocropping. Sweetpotato played a dominant role in these systems, contributing the majority to the total LER and reinforcing its importance in driving the efficiency of the intercropping systems.

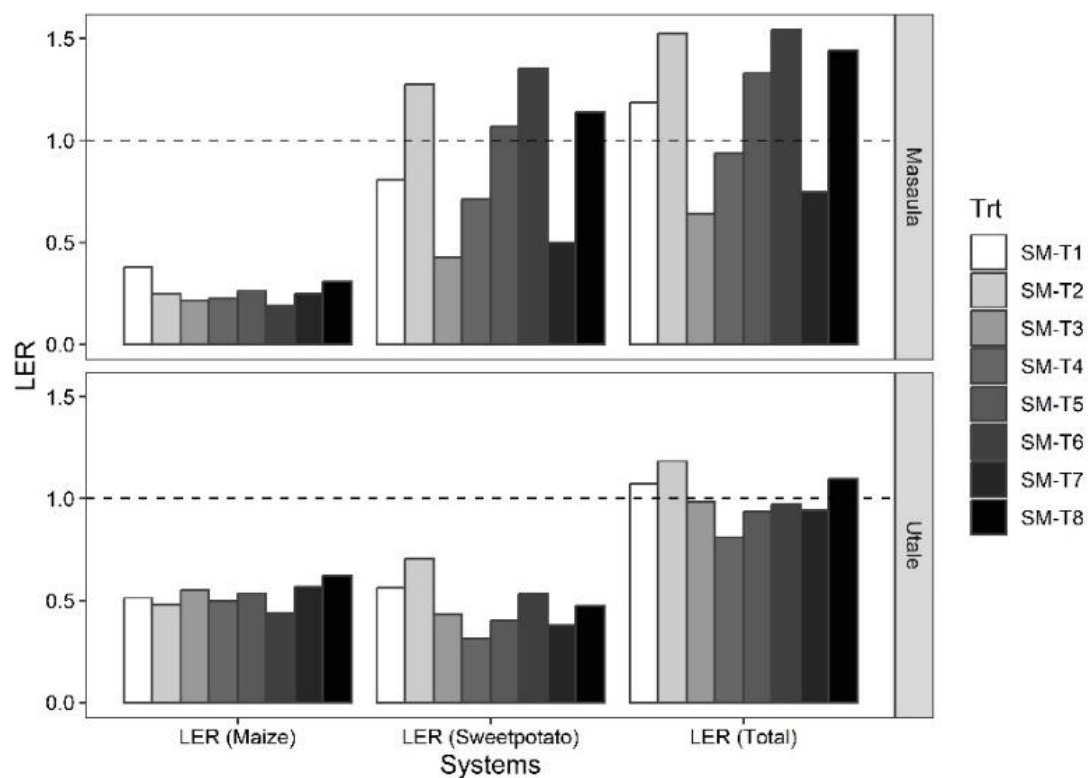


Figure 4. Partial and total Land Equivalent Ratio for sweetpotato and maize intercrop systems

Although there was no significant difference in the Land Equivalent Coefficient (LEC) among the intercropping treatments. Certain intercropping systems demonstrated higher productivity ($LEC > 0.25$) compared to the component crops grown as sole crops. Notably, 4 ridges of maize at 75cm alternating 4 ridges of sweetpotato at 100cm intercropping exhibited superior productivity in both Masaula and Utale, while intercropping with 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 75cm (T1) and intercropping with 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 100cm (T2) showed enhanced performance in Utale (Figure 5).

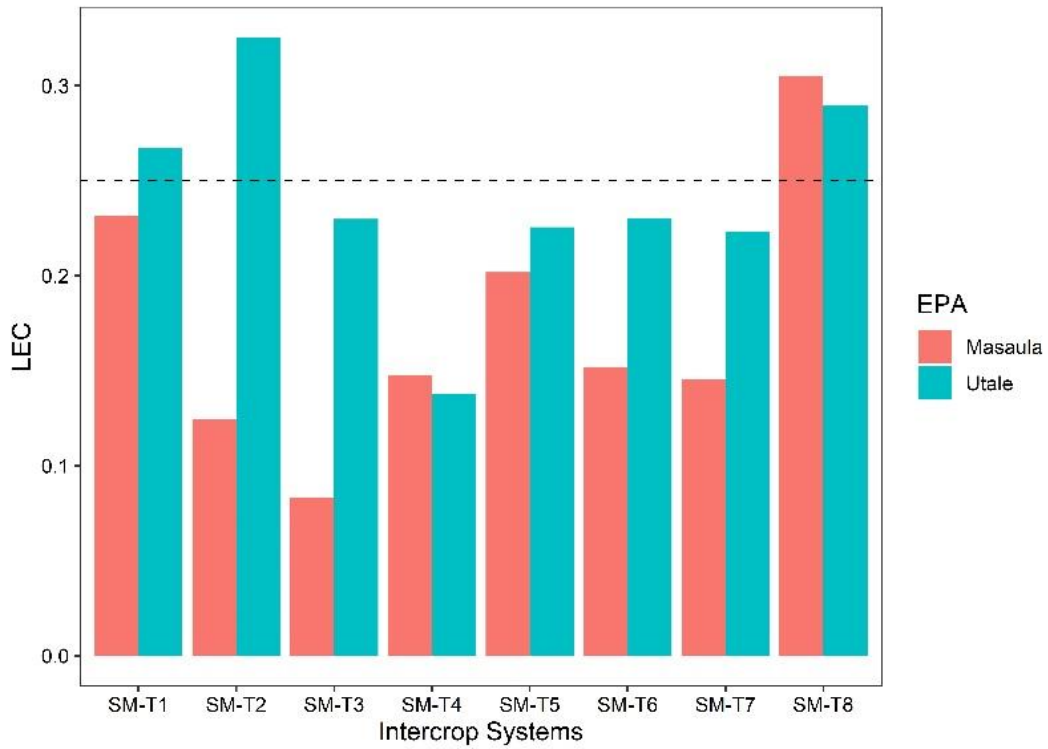


Figure 5. Land Equivalent Coefficient for sweetpotato and maize intercrop systems

Sweetpotato equivalent yield (PEY) did not vary significantly among the treatments, however figure 6 shows that PEY was positively correlated with sweetpotato yield. The linear relationship suggests that higher sweetpotato yields consistently resulted in higher equivalent economic returns across the intercropping systems.

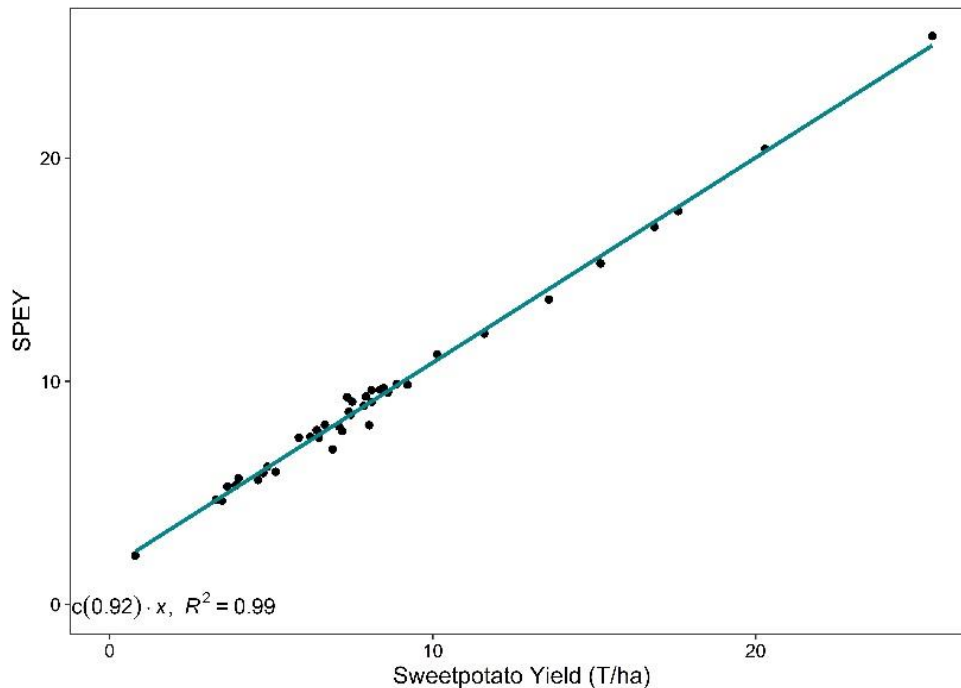


Figure 6. Relation between Sweetpotato equivalent yield and sweetpotato root yield

5. Discussion

The results of this study highlight the potential of maize-sweetpotato intercropping as a promising strategy to enhance the resilience and productivity of maize-based systems in drought-prone areas of Malawi. With maize remaining the cornerstone of food security, especially in regions facing the increasing threat of climate change, identifying efficient and resilient cropping systems is critical for achieving food security (Tanumihardjo et al., 2020). The 2023/24 cropping season, marked by the El Niño weather phenomenon, exemplified the climate-induced challenges smallholder farmers face. The delayed rains, prolonged dry spells, and low rainfall significantly impacted crop yields, particularly for maize, which saw a 16% decline nationally (UN Malawi, 2024). Similarly, this study's crop performance reflected these challenges, with average yields of 1.9 t/ha for maize and 19 t/ha for sweetpotato both below the national averages, primarily due to late planting and moisture stress during critical growth stages (FAO, 2022). Despite these adversities, the intercropping of sweetpotato with maize demonstrated higher equivalent yields compared to sole cropping. This highlights its potential as a strategic intervention to mitigate climate-related impacts while enhancing overall system productivity.

6. Component crops yield under sole and intercrops

Intercropping maize with drought-tolerant crops such as sweetpotato presents an important diversification strategy to stabilize and potentially increase overall system productivity. As anticipated, maize yield was higher in the sole cropping system compared to intercropping, whereas sweetpotato root yield exhibited a different trend. The lower maize yield under intercropping, consistent with findings by Feng et al. (2021), can be attributed to the reduced plant population associated with row-replacement intercropping arrangements.

In contrast, sweetpotato root yields under certain intercropping treatments, such as 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 100cm (T2), 4 ridges of maize at 50cm alternating 4 ridges of sweetpotato at 100cm (T6) and 4 ridges of maize at 75cm alternating 4 ridges of sweetpotato at 100cm (T8), were comparable to those in the sole sweetpotato cropping system. These treatments utilized wider ridge spacing (100 cm), likely reducing competition for light and shading. This arrangement created favorable conditions for complementary growth in sweetpotato, resulting in overyielding within these intercropping systems. These findings align with those of Mbayaki and Karuku (2021), who observed similar sweetpotato yields under intercropping with beans and sole cropping while Munda et al. (2019) reported higher sweetpotato yields in intercropping systems compared to sole cropping. These results emphasize the resilience potential of sweetpotato, which, coupled with its tolerance to poor soils, water stress, and shorter growth cycle, makes it ideally suited for integration into maize-based systems, thereby enhancing their overall resilience (Kumar et al., 2022; Yadav et al., 2024).

It is worth noting that both sole and intercropped maize grain yields were below the national 5-year average of 2.1 t/ha, largely due to prolonged dry spells attributed to the El Niño phenomenon (UN Malawi, 2024). In contrast, sweetpotato mean yields was equally affected below the national average yield of 23 t/ha recorded in 2022 (FAO, 2022), but some farmers individual fields recorded higher yields equal to the national average highlighting its adaptive potential to drought conditions.

7. Resource Use Efficiency and Economic Viability

One of the key advantages of intercropping is the improved resource use efficiency, particularly in terms of light, water, and nutrients. The results showed that intercrop systems 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 75cm (T1), 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 100cm (T2), and 4 ridges of maize at 75cm alternating 4 ridges of sweetpotato at 100cm (T8) achieved LER values greater than 1 in all the sites (figure 4 and 5), suggesting that these combinations used land resources more efficiently than monocropping systems. This finding aligns with previous research, such as Abidin et al. (2015) and (Gitari et al., 2020), which suggests that sweetpotato in intercropping systems can enhance productivity due to its complementary growth characteristics with other crops. Notably, these results show that sweetpotato contributed a significant portion of the total productivity in the intercrop systems (Figures 4 and 6), underscoring its crucial role in optimizing land use efficiency. However, contrary to findings by Li et al. (2020) and Zhao et al. (2023), who reported maize as the dominant species in maize-based intercropping systems, sweetpotato was the more dominant crop in this study. This discrepancy could be attributed to dry spells that significantly affected maize performance compared to the more resilient sweetpotato.

The productivity efficiency of the sweetpotato-maize intercropping systems was further demonstrated by the positive productivity values, with an LEC > 0.25 in intercrop systems comprising of 2 ridges of maize at 50cm alternating with 2 ridges of sweetpotato at 75cm (T1), 2 ridges of maize at 50cm alternating with 2 ridges of sweetpotato at 100cm (T2), and 4 ridges of maize at 75cm alternating with 4 ridges of sweetpotato at 100cm (T8), with , 2 ridges of maize at 50cm alternating with 2 ridges of sweetpotato at 100cm showing particularly strong performance. These results underscore the potential of sweetpotato intercropping to sustain agricultural production under adverse conditions, while providing economic resilience for smallholder farmers in drought-prone areas.

8. Challenges and Considerations for Adoption

In this study, the intercropping arrangement treatments comprising 2 ridges of maize at 50cm alternating with 2 ridges of sweetpotato at 75cm (T1), 2 ridges of maize at 50cm alternating with 2 ridges of sweetpotato at 100cm (T2), and 4 ridges of maize at 75cm alternating with 4 ridges of sweetpotato at 100cm (T8) have shown outstanding performance that would be recommended by for farmers. The intercropping arrangement are treatments based on narrow spaced – 2 row ridges of maize and sweetpotato (T1) while T2 is closely spaced 2 rows of maize and widely spaced 2 rows of sweetpotato while T8 is a widely spaced 4 rows of maize and sweetpotato. However, in a similar study, Abidin et al. (2015) reported that farmers preference of sweetpotato-maize spatial arrangements changed but indicated strong preference of higher sweetpotato-density (two rows sweetpotato: one row maize) arrangement closely resembling treatment with 2 ridges of maize at 50cm alternating with 2 ridges of sweetpotato at 75cm (T1). While the spatial arrangements of T2 and T8, are quite different with wider sweetpotato spacing, but the results in our study showed wider ridge spacing enhanced sweetpotato yield.

Previous research has noted that the shading effect of maize may reduce the light available to sweetpotato (Oswald et al., 1996; Yulong et al., 2017), which could explain the lower root yields observed in some treatments, as the case of 2 ridges of maize at 75cm alternating with 2 ridges of sweetpotato at 75cm and 4 ridges of maize at 75cm alternating with 4 ridges of sweetpotato at 75cm in this study.

The positive correlation between sweetpotato yield and Equivalent Yield (PEY) suggests that maximizing sweetpotato yields in intercropping systems will be crucial to improving the overall economic returns of sweetpotato-maize intercrop systems (Figure 6). This finding aligns with the conclusions of Abidin et al. (2015) which highlighted that higher sweetpotato yields lead to improved economic returns. Therefore, based on our results, it is essential for farmers and extension services to focus on sweetpotato-maize intercropping systems that optimizes plant densities and spatial arrangements. Such practices will help ensure that both crops in intercropping systems reach their full potential, as emphasized by Stomph et al. (2020).

9. Conclusion and Recommendations

The results of this study highlight the significant potential of sweetpotato-maize intercropping systems to improve productivity and economic returns in drought-prone areas. Intercropping sweetpotato with maize not only enhances the productivity efficiency of the cropping system, but also provides economic resilience, particularly for smallholder farmers. The Intercrop arrangement treatments 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 75cm (T1), 2 ridges of maize at 50cm alternating 2 ridges of sweetpotato at 100cm (T2), and 4 ridges of maize at 75cm alternating 4 ridges of sweetpotato at 100cm (T8), with $LEC > 0.25$ and $LER > 1$, are particularly recommended for use by farmers to improve productivity and enhance resilience of maize-based systems. Further studies are needed to refine the optimal spatial arrangements and plant densities for sweetpotato-maize intercropping in various agro-ecological zones. Based on the observed positive performance of intercropping systems, it is recommended that farmers and extension services focus on optimizing plant densities and spatial arrangements. This would help maximize resource utilization and yield potential under diverse climatic conditions.

10. References

- Abidin, P., Chipungu, F., Nyekanyeka, T., Chilanga, T., Mwenye, O., Kazembe, J., Botha, B., & Carey, E.** (2015). Maize-orange-fleshed sweetpotato intercropping: potential for use to enhance food security and scaling-up the nutrition effort in Malawi. In *Potato and sweetpotato in Africa: transforming the value chains for food and nutrition security* (pp. 405-413). CABI Wallingford UK.
- Anderson, J., & Ingram, J.** (1993). A handbook of methods. *CAB International, Wallingford, Oxfordshire*, 221, 62-65.
- Bahadori, M., & Tofighi, H.** (2016). A modified Walkley-Black method based on spectrophotometric procedure. *Communications in Soil Science and Plant Analysis*, 47(2), 213-220.
- Chamasula, V., & Rabumbulu, M.** (2024). An investigation of how to address climate change-induced land degradation in Balaka, Malawi, by reconciling indigenous and scientific knowledge [Original Research]. *Frontiers in Human Dynamics*, 6. <https://doi.org/10.3389/fhumd.2024.1450651>
- FAO.** (2018). *Soil nutrients loss assessment in Malawi - Technical Report*. <https://openknowledge.fao.org/server/api/core/bitstreams/95650e64-06d4-4b3e-8039-12a2a52d7a01/content>
- FAO.** (2022). *FAOSTAT: Crops and livestock products*. <https://www.fao.org/faostat/en/#data/QCL>
- Feng, L., Yang, W., Zhou, Q., Tang, H., Ma, Q., Huang, G., & Wang, S.** (2021). Effects of interspecific competition on crop yield and nitrogen utilisation in maize-soybean intercropping system. *Plant, Soil & Environment*, 67(8).
- Gelaye, Y.** (2024). Sweet potato: a versatile solution for nutritional challenges in Ethiopia. *Technology in Agronomy*, 4(1).
- Girard, A. W., Brouwer, A., Faerber, E., Grant, F. K., & Low, J. W.** (2021). Orange-fleshed sweetpotato: Strategies and lessons learned for achieving food security and health at scale in Sub-Saharan Africa. *Open Agriculture*, 6(1), 511-536.
- Gitari, H. I., Nyawade, S. O., Kamau, S., Karanja, N. N., Gachene, C. K. K., Raza, M. A., Maitra, S., & Schulte-Geldermann, E.** (2020). Revisiting intercropping indices with respect to potato-legume intercropping systems. *FIELD CROPS RESEARCH*, 258, 107957. <https://doi.org/https://doi.org/10.1016/j.fcr.2020.107957>
- Katuromunda, S.** (2021). Growth and Yield Response of Improved Sweet Potato Cultivars to Intercropping with Hybrid Maize and Inorganic Fertilizers. *Journal of Plant Sciences*, 9(6), 289-298.
- Kumar, R., Krishna, B., Sundaram, P. K., Kumawat, N., Jeet, P., & Singh, A. K.** (2022). Crop Diversification: An Approach for Productive and Climate-Resilient Production System. *Sustainable agriculture systems and technologies*, 63-80.
- Li, C., Hoffland, E., Kuyper, T. W., Yu, Y., Li, H., Zhang, C., Zhang, F., & van der Werf, W.** (2020). Yield gain, complementarity and competitive dominance in intercropping in China: A meta-analysis of drivers of yield gain using additive partitioning. *EUROPEAN JOURNAL OF AGRONOMY*, 113, 125987. <https://doi.org/https://doi.org/10.1016/j.eja.2019.125987>
- Low, J. W., Ortiz, R., Vandamme, E., Andrade, M., Biazin, B., & Grüneberg, W. J.** (2020). Nutrient-Dense Orange-Fleshed Sweetpotato: Advances in Drought-Tolerance Breeding and Understanding of Management Practices for Sustainable Next-Generation Cropping Systems in Sub-Saharan Africa [Review]. *FRONTIERS IN SUSTAINABLE FOOD SYSTEMS*, 4. <https://doi.org/10.3389/fsufs.2020.00050>
- Mbayaki, C. W., & Karuku, G. N.** (2021). Growth and yield of sweet potato (*Ipomoea batatas* L.) monocrops versus intercrops in the semi-arid Katumani, Kenya. *Tropical and Subtropical Agroecosystems*, 24(3).
- Mead, R., & Willey, R. W.** (1980). The Concept of a 'Land Equivalent Ratio' and Advantages in Yields from Intercropping. *Experimental Agriculture*, 16, 217 - 228.
- MoAIWD.** (2021). *Guide to Agriculture Production and Natural Resources Management in Malawi*. Agriculture Communication Branch, Department of Agriculture Extension Services Ministry of Agriculture.

- Munda, E., Pieterse, P. J., Andrade, M. I., Makunde, G. S., & Pereira, E. I.** (2019). Improving productivity of orange-fleshed sweetpotato (*Ipomoea batatas*) through intercropping with legumes and moderate phosphorus application. *SOUTH AFRICAN JOURNAL OF PLANT AND SOIL*, 36(3), 221-228.
- Nayan, G. Z., Takim, F. O., Aremu, C. O., & Okunola, A. A.** (2020). Effect of maize sweet potato intercrop over sole cropping system on weed infestation. *IOP Conference Series: Earth and Environmental Science*, 445(1), 012007. <https://doi.org/10.1088/1755-1315/445/1/012007>
- Ostatek-Boczynski, Z. A., & Lee-Steere, P.** (2012). Evaluation of Mehlich 3 as a Universal Nutrient Extractant for Australian Sugarcane Soils. *Communications in Soil Science and Plant Analysis*, 43(4), 623-630. <https://doi.org/10.1080/00103624.2012.643845>
- Oswald, A., Alkämper, J., & Midmore, D.** (1996). The Response of Sweet Potato (*Ipomoea batatas* Lam.) to Inter- and Relay-cropping with Maize (*Zea mays* L.). *Journal of Agronomy and Crop Science*, 176(4), 275-287.
- Snapp, S. S.** (1998). Soil nutrient status of smallholder farms in Malawi. *Communications in Soil Science and Plant Analysis*, 29(17-18), 2571-2588.
- Stevens, T., & Madani, K.** (2016). *Future climate impacts on maize farming and food security in Malawi*. <http://www.nature.com/articles/srep36241>
- Stomph, T., Dordas, C., Baranger, A., de Rijk, J., Dong, B., Evers, J., Gu, C., Li, L., Simon, J., Jensen, E. S., Wang, Q., Wang, Y., Wang, Z., Xu, H., Zhang, C., Zhang, L., Zhang, W.-P., Bedoussac, L., & van der Werf, W.** (2020). Chapter One - Designing intercrops for high yield, yield stability and efficient use of resources: Are there principles? In D. L. Sparks (Ed.), *Advances in Agronomy* (Vol. 160, pp. 1-50). Academic Press. <https://doi.org/https://doi.org/10.1016/bs.agron.2019.10.002>
- Tanumihardjo, S. A., McCulley, L., Roh, R., Lopez-Ridaura, S., Palacios-Rojas, N., & Gunaratna, N. S.** (2020). Maize agro-food systems to ensure food and nutrition security in reference to the Sustainable Development Goals. *Global Food Security*, 25, 100327.
- UN Malawi.** (2024). *Socio-Economic Effects of El Niño in Malawi and Implications for Recovery and Long-Term Resilience Building*. <https://reliefweb.int/report/malawi/socio-economic-effects-el-nino-malawi-and-implications-recovery-and-long-term-resilience-building-july-2024>
- Warnatzsch, E. A., & Reay, D. S.** (2020). Assessing climate change projections and impacts on Central Malawi's maize yield: The risk of maladaptation. *SCIENCE OF THE TOTAL ENVIRONMENT*, 711, 134845-134845. <https://doi.org/10.1016/j.scitotenv.2019.134845>
- Wendt, J.** (1996). Soil and plant analytical laboratory manual. *Bunda College of Agriculture*.
- Yadav, D., Babu, S., Yadav, D. K., Kumawat, A., Singh, D., Yadav, A. K., Rathore, S. S., Singh, R., Joshi, N., Yadav, R. K., & Das, A.** (2024). Cropping System Intensification: Implications on Food Security and Environmental Sustainability in India. *Anthropocene Science*, 3(1), 1-22. <https://doi.org/10.1007/s44177-024-00078-4>
- Yulong, L., Xueli, W., Daobin, T., Xun, L., Yayun, L., Changwen, L., & Jichun, W.** (2017). Effect of maize (*Zea mays* L.) plant-type on yield and photosynthetic characters of sweet potato (*Ipomoea batatas* L.) in intercropping system. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 45(1), 245-254.
- Zhao, J., Bedoussac, L., Sun, J., Chen, W., Li, W., Bao, X., van der Werf, W., & Li, L.** (2023). Competition-recovery and overyielding of maize in intercropping depend on species temporal complementarity and nitrogen supply. *FIELD CROPS RESEARCH*, 292, 108820. <https://doi.org/https://doi.org/10.1016/j.fcr.2023.108820>
- Zuza, E., Ankrumah, K., Maseyk, Y. N., Araya, A., Emmott, W., Rawes, Shonil, B., Frank, M., & Wayne, W. H.** (2022). *Soil types in Malawi*. <https://doi.org/10.6084/m9.figshare.21295671.v1>

WWW.CIPOTATO.ORG

The International Potato Center (CIP) was founded in 1971 as a research-for-development organization with a focus on potato, sweetpotato and Andean roots and tubers. It delivers innovative science-based solutions to enhance access to affordable nutritious food, foster inclusive sustainable business and employment growth, and drive the climate resilience of root and tuber agri-food systems. Headquartered in Lima, Peru, CIP has a research presence in more than 20 countries in Africa, Asia and Latin America.

www.cipotato.org

CIP is a CGIAR research center, a global research partnership for a food-secure future. CGIAR science is dedicated to transforming food, land and water systems in a climate crisis. Its research is carried out by 13 CGIAR Centers/Alliances in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations and the private sector.

www.cgiar.org

For more information, please contact CIP Headquarter. Av. La Molina 1895, La Molina. Apartado 1558, Lima 12, Peru.

☎ 5-11-3496017 ✉ cip-cpad@cgiar.org 🌐 www.cipotato.org | 📘 @cipotato ✂ @Cipotato 📷 @cip_potato

CIP thanks all donors and organizations that globally support its work through their contributions to the CGIAR Trust Fund: www.cgiar.org/funders



© 2024. This publication is copyrighted by the International Potato Center (CIP). It is licensed for use under the Creative Commons Attribution 4.0 International License