RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Determinants of Maize Production: Intercropping Maize and Beans in South Western Uganda

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10.18805/ag.DF-601

ABSTRACT

Background: Intercropping is the practice of growing two or more crops nearby: in the same row or bed, or rows or strips near enough to allow biological interactions. Advantages of inter cropping include: improving soil's nutrients to better support crops' growth and development thus improving yields; it improves soil-water retention and diversifies the farmers' incomes in case of failure for one crop. It is one of the natural methods for management of crop pests and diseases. Inter cropping maize and beans is one of the climate-smart agricultural approaches used to boost crop production across the globe. However, some smallholder farmers have a negative attitude toward it due to limited knowledge regarding its benefits. The study aimed at establishment of the effect of intercropping maize and beans on the maize yields in Isingiro District, South Western Uganda.

Methods: The experiment was conducted in two seasons (March-May 2020 and August- November 2021). Standard agronomical practices were followed from planting to harvesting, after which the dry weight of maize was measured and recorded. Data analysis was done using ONEWAY ANOVA in R Software Version 4.2.2.

Result: Results show that intercropping maize and beans in season one significantly increased maize yields ($p<0.001$) more than it did in season two ($p=0.0211$). The main effect of Season is statistically significant and large ($p<.001$). The main effect of Treatment is statistically significant and large ($p<.001$). The study concluded that reduced rainfall negatively affects maize yields and intercropping Longe5 with NABE16 increases maize yields. Early planting and good agronomic practices were recommended to improve maize productivity.

Key words: Climate change, Climate-smart agriculture, Heavy rains, High temperature, Intercropping, Maize yields, Variability.

INTRODUCTION

Climate change has the potential to alter food availability, restrict access to food and degrade food quality. Temperature increases, changes in precipitation patterns, changes in extreme weather events and reduced water availability, for example, could all result in lower agricultural production. Climate change and climate variability have threatened food and income security in many vulnerable Sub-Saharan Africa (SSA) countries (Godfray, 2010; Torquebiau *et al*., 2018). Previous studies conducted in Malawi projected that rain-fed maize production in Lilongwe may decrease up to 14% and may reach 33% by mid-century because of climate change resulting in increased household poverty and food insecurity in the country (Msowoya and Madani, 2016). Technology-driven and innovative solutions can boost agricultural yields and food output to fulfill the food and fiber demands of the region's rapidly rising populations. Smallholder farmers should use resilient agricultural innovations that can endure climate change and variable challenges in developing nations in the twenty-first century to increase maize productivity. Intercropping maize and wheat, for example, increased yield and water retention in China (Jun-bo *et al*., 2018), thereby increasing crop productivity, while intercropping maize and wheat increased yield components of wheat and maize in a wheat-maize intercropping system in the Netherlands (Gou, 2017) and conservation agriculture in Malawi increased maize resistance to climate stress (Steward *et al*., 2019). On the other hand, intercropping of maize, millet, mustard, wheat and ginger was reported to

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How to cite this article: Tumwesigye, W., Osiru, D., Benard, L., Tefera, T.L., Bedadi, B., Jackson-Gilbert, M.M., Bamwesigye, D. and Chavula, P. (2024). Determinants of Maize Production: Intercropping Maize and Beans in South Western Uganda. Agricultural Science Digest. doi: 10.18805/ag.DF-601.

Submitted: 24-01-2024 **Accepted:** 20-06-2024 **Online:** 23-07-2024

have increased land productivity and economic returns for smallholder farmers in Nepal (Chapagain *et al*., 2018). Intercropping not only promotes food security, but it also can increase farmer income and alleviate poverty in developing nations such as Uganda. Maize productivity increased significantly and improved farmers‘ income in an Indian Maize based intercropping system(Sannagoudar *et al*., 2021). Furthermore, intercropping wheat and maize with straw mulching on the soil surface was reported to improve the super-compensatory effect of late-maturing maize, thus improving total yield in intercropping systems in arid oasis areas of China (Canisares *et al*., 2021) and intercropping with reduced Nitrogen rate maintained sweet maize production while reducing environmental impacts and climate change (Xiao *et al*., 2018). Although various research on the benefits of legumes and cereals intercropping systems have been conducted in SSA countries (Canisares *et al*., 2021; Hailu *et al*., 2018; Mpairwe *et al*., 2003), there is a lack of knowledge regarding its benefits in Isingiro District. The purpose of this study was to determine the influence of intercropping maize and beans on maize yields in Isingiro Town Council, Isingiro District, South Western Uganda.

Core ideas

- Intercropping Longe 5 and flint corn with NABE16 beans increase maize productivity.
- Maize productivity for season one (March to May) is higher than season two (September to December) because rainfall is appropriate in season one and too much in season two.
- Intercropping Velvet beans and maize reduces maize yields due to over-competition for light and soil nutrients.
- Velvet beans should be planted three weeks after maize to minimize the effect of competition.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted in Isingiro Town Council (Fig 1) with geographic coordinates of 0°47′42.08″S and 30°48′57.18″E. The average annual rainfall range is 973 mm-1200 mm and the average temperature is between 15.17°C and 27.18°C. The area has a tropical climate and Acrisol soils which have rich clay content and limited soil nutrients thus potential for crop productivity (Ekesa *et al*., 2015). The soils are less fertile and the primary crops grown in the area, supported by fertilizers (both organic and artificial), include: -bananas, coffee, beans and maize for supporting household food and income security (ACORD, 2010). Isingiro District is highly vulnerable to a prolonged meteorological drought that undermines crop productivity and smallholder farmers’ livelihoods (Twongyirwe *et al*., 2019). The majority of the population in the sub-county are smallholder poor farmers with small pieces of land (less than 2 ha). They are dependent on rainfed agriculture for their livelihoods (ILG, 2009). The region is located in the dry cattle corridor, with inadequate household, industrial and agricultural water resources. The scarcity of groundwater is a limiting factor for effective agriculture productivity and animal husbandry. In the recent decade, the Prime Minister’s Development Response to Displacement Impact Project (DRDIP) has sponsored agricultural projects to address the problem of water scarcity. These include, among other things, drip irrigation, water harvesting, agroforestry and tree planting to restore degraded environments.

Experimental design

Fig 2 presents a randomized complete block design (RCBD) experimental plots that were used for this experiment. Eight treatments in 4 replicas of each were used to make a total of 32 plots. Only six treatments involving maize varieties were used for this publication. Two varieties of maize (Longe5-high yielding and Flint corn-low yielding) were intercropped with two varieties of beans (NABE16 and Velvet bean) in lines on a one-acre piece of land. Maize (*Zea mays*) was intercropped with NABE16 (*Phaseolus vulgaris* L.) and velvet beans [*Mucuna pruriens* (L.) DC var. utilis]. Monocropping systems were used as control experiments for each variety. The RCBD approach was used for this experiment because it is robust in intercropping and yields appropriate data for statistical scientific analysis (Plant, 2014).

Data analysis

Data were analyzed using R-Software version 4.2.2 using appropriate packages fit for the RCBD experiments as recommended by previous scholars (Hornik, 2022). Descriptive statistics mean and standard deviations of Maize yields from six (6) treatments across two seasons (March-May and September-November) were computed using the daily function of ‘plyr’ package of R Software (Venables and Smith, 2022) and the results are presented in Table 1.

Compact letter display (CLD) interpretation key

“a” “b” “ab” “c”

The above indicates that the first variable “a” has a mean that is statistically different from “b” the third variable “bc” and the fourth one “c”. But, this first variable “a” is not statistically different from the second one “ab”.

Results in Table 2 reveal that the mean maize yield is higher in season one than in season two. The maize yield was found to be higher during season one (March-May) than in season two (September-November) for all six treatments. The highest mean maize yield (2.081 tons/ha) was observed when Longe5 was intercropped with NABE16 and the lowest yield (0.341 tons/ha) was obtained when Velvet bean was intercropped with flint corn.

Descriptive statistics results in Table 1 show that for all 6 treatments, maize yields were higher in March-May (season one) than September-November (season two). The Table 3 shows maize yields in tons/ha for the March-

May and September-November seasons respectively per treatment. The highest intercropping mean maize yield in the March-May season was observed from L5NABE16 (2.778/1.384 tons/ha) followed by FCNABE16 (1.747/0.984 tons/ha). The least intercropping maize yield was observed from FCVB (0.600/0.081 tons/ha).

Box plots for all 6 treatments (Fig 3) show the effect of intercropping beans with maize in both the March-May and September-November seasons. Intercropping Longe5 with nambare16 (L5NB16) showed the highest yield (2.778 tons/ha) in the March-May season) and intercropping flint corn with velvet beans (FCVB) had the lowest yield (0.6 tons/ha in the March-May season (0.08 tons/ha) in the September-November season). The mean maize yields are generally lower in the September-November season than the March-May season for all treatments.

Analysis of variance

The test was carried out using the above function from the 'stats' package of R Software (Venables and Smith, 2022). Effect sizes were labeled following field recommendations (Field, 2016).

The analysis using ANOVA (Table 3) (formula: Yield ~ Season + Treatment + Season * Treatment) yields the following results:

1) The main effect of Season is statistically significant and large [F (1, 41) = 23.86, p<.001; Eta 2 (partial) = 0.37, 95% CI (0.18, 1.00)].
2) The main effect of treatment is statistically significant and large [F (5, 41) = 10.87, p<.001; Eta2 (partial) = 0.57, 95% CI (0.37, 1.00)].
3) The interaction between season and treatment is statistically not significant and large [F (5, 36) = 1.42, p = 0.242; Eta 2 (partial) = 0.16, 95% CI (0.00, 1.00)].

Pairwise comparisons

A pairwise comparison of all treatments was carried out to find significant differences between treatments.

Table 4 presents the results for pairwise comparisons of all treatment pairs. The following pairs show a very high statistical significance at a 1% significant level: SFC - FCVB (p<0.001); SL5 - FCVB (p<0,001) and L5NB16 - L5VB (p<0.001). The pairs that show statistical significance at a 10% significant level include FCNB16 – FCVB (p = 0.014); L5VB – SFC (p = 0.002) and SL5 - L5VB (p = 0.012).

RESULTS AND DISCUSSION

Intercropping is a climate-smart alternative that has the potential to help soils, microorganisms, climate change mitigation, crop yield and the income of smallholder farmers, among other things. Season one (March-May) offered adequate sunlight and rainfall for improved maize productivity. As a result, maize yields were greater and statistically significant (p 0.001). However, harvests were lowered for season two (September-November) due to severe rainfall and insufficient sunshine, which hampered maize yields. Furthermore, velvet beans rose and outcompeted maize for both sunshine energy and soil nutrients in the second season, leading to low maize yields. The findings of this study agree with previous studies conducted in the USA that pointed out that lablab

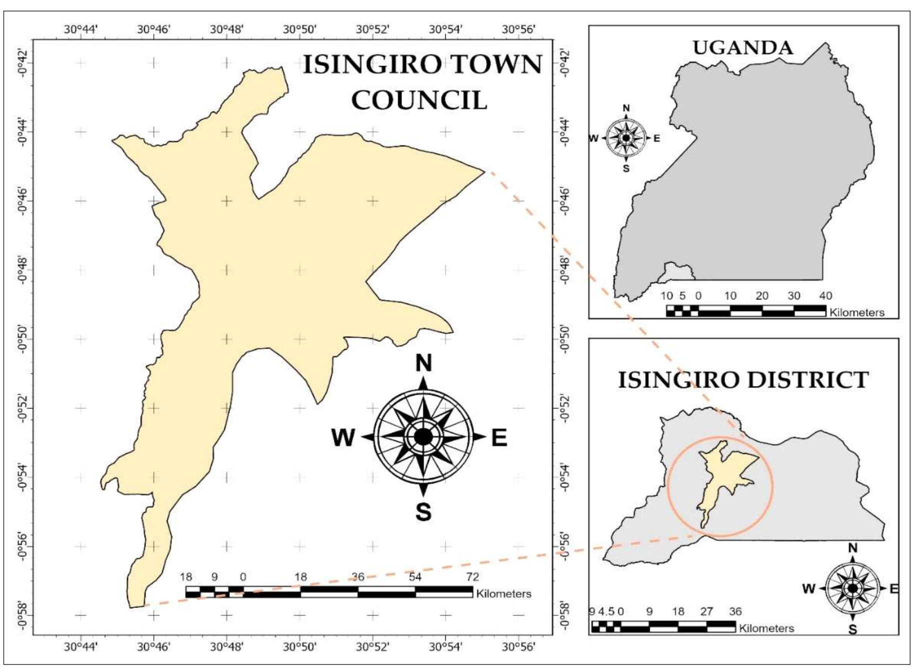

Fig 1: Map of Uganda showing the location for Isingiro Town Council in Isingiro District.

bean intercropped with corn increased crude protein higher than those grown in Monocropping experimental plots (Armstrong *et al*., 2008).

Intercropping maize with legumes reduced pest and disease infestations in the planting system, enhancing crop production and smallholder farmer incomes in the region (FAO, 2011). Similar studies in Morocco found that intercropping barley with faba bean benefited barley plants but not faba beans in terms of shoot and root biomasses and Phosphorus contents, promoting the former's growth and development for use in livestock feeds (Kaci *et al*., 2018). Similarly, studies in Western Kenya found that intercropping maize with crotalaria, groundnut and green gram had considerable economic benefits because all farming methods enhanced land productivity, household food security and income security over maize mono-cropping (Midega *et al*., 2014). According to the study, intercropping maize with groundnuts improved soil nutrients and maximized the use of natural resources, resulting in greater maize productivity (Nyirenda and Balaka, 2021). At the same time, studies conducted in Ethiopia pointed out that intercropping of maize with different crops including

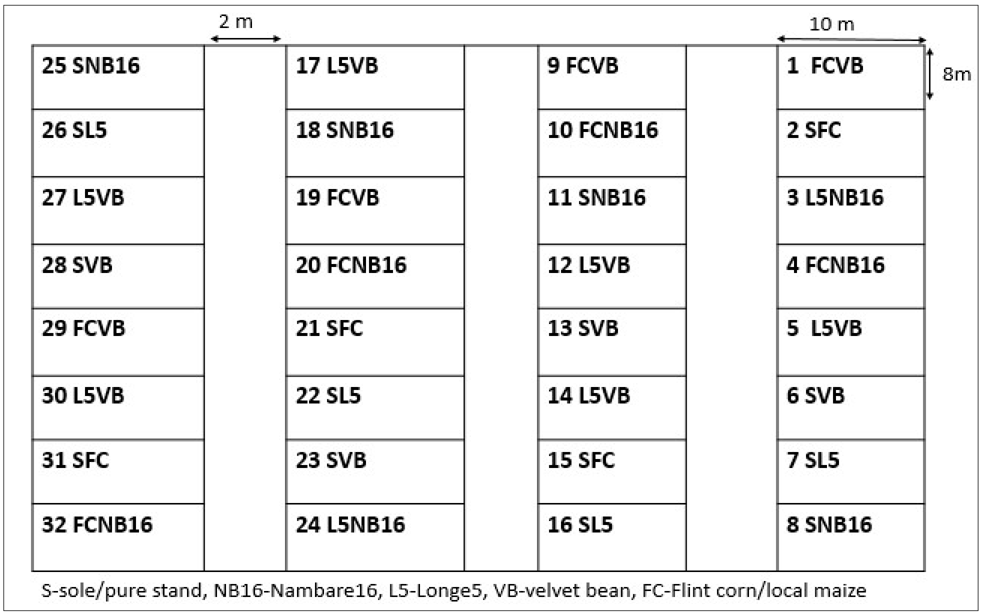

Fig 2: RCBD Intercropping experimental design.

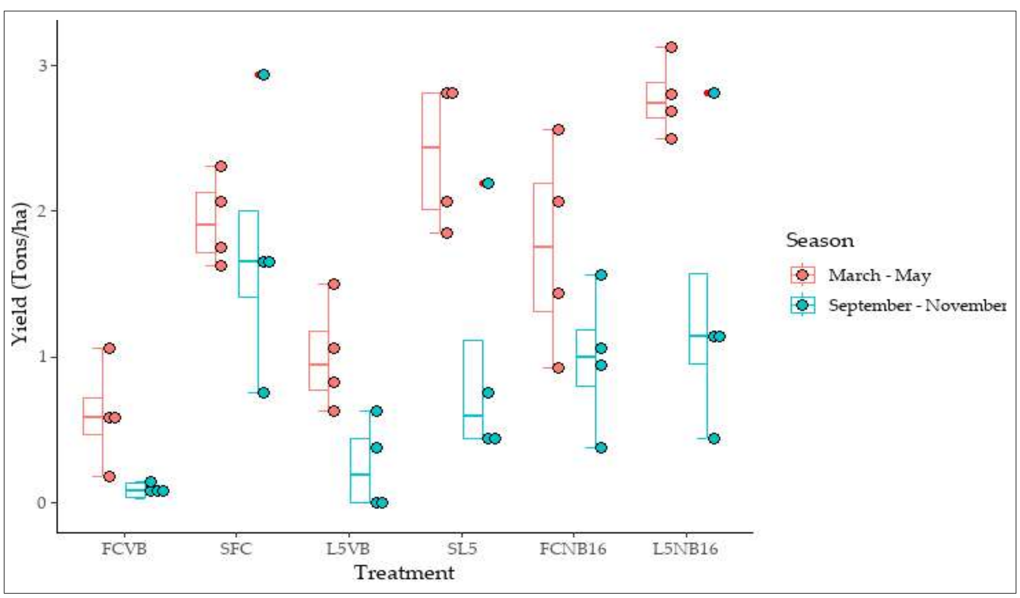

Fig 3: Boxplot of treatment on yield disaggregated by season.

soybean and desmodium resulted in reduced termite damage to maize and increased maize yield for improved farmers' livelihoods (Demissie *et al*., 2019). Similarly, intercropping maize with cowpeas reduced pest incidence hence improving maize productivity thus agreeing with this study (Singh *et al*., 2023).

Furthermore, research conducted in Tigray, Ethiopia found that planting one maize and two potato rows demonstrated a 58% yield gain over solitary cropping, enhancing household food security and income (Kidane *et al*., 2017). This study's findings corresponded with those of another study conducted in Alvorada do Gurguéia, which concluded that intercropping maize with cover crops boosted maize grain production, macronutrient contents, straw dry matter accumulation and cowpea grain output (Batista De Morais *et al*., 2020). The study agreed with similar studies conducted in India which found that intercropping maize with soya bean improved maize yields (Talukdar *et al*., 2022). In addition, research conducted in China revealed that strip intercropping of maize and soybean improved maize absorption of nitrogen, phosphorus and potassium while preventing continuous cropping, increased plant density and achieved a high yield of both crops in the intercropping systems, resulting in increased crop productivity (Jun-bo *et al*., 2018).

Velvet beans, on the other hand, outperformed maize plants for soil nutrients, light and water in season two (September-November), reducing maize yield. These

Table 1: Descriptive statistics-mean yield per treatment and season.

	Mean yield (Ton/ha)	Std. Dev	Min	Max
Treatment				
FCVB	0.341c	0.367	0.025	1.063
SFC	1.844ab	0.631	0.750	2.938
L5VB	0.627c	0.513	0.000	1.500
SL5	1.669ab	0.996	0.438	2.813
FCNB16	1.366b	0.698	0.375	2.563
L5NB16	2.081a	1.010	0.438	3.125
Season				
March-May	1.742a	0.862	0.175	3.125
September-November	0.901b	0.855	0.000	2.938

Key- 1: FCVB - Flint corn intercropped with velvet beans; 2:SFC-Pure stand flint corn; 3: L5VB - Longe5 intercrop with velvet bean; 4: SL5- Pure stand longe 5; 5: FCNB16 - Flint corn intercrop with Nambare 16; 6: L5NB16- Longe 5 intercropped with Nambare16.

Table 2: Comparison of maize yields for each treatment in season one and season two.

Treatment	Season	Mean yield (Ton/ha)	Std. Dev	Min	Max
FCVB	March-May	0.600	0.363	0.175	1.063
	September-November	0.081	0.058	0.025	0.138
SFC	March-May	1.938	0.310	1.625	2.313
	September-November	1.750	0.900	0.750	2.938
L5VB	March-May	1.003	0.376	0.625	1.500
	September-November	0.250	0.306	0.000	0.625
SL5	March-May	2.384	0.502	1.850	2.813
	September-November	0.953	0.836	0.438	2.188
FCNB16	March-May	1.747	0.716	0.925	2.563
	September-November	0.984	0.488	0.375	1.563
L5NB16	March-May	2.778	0.262	2.500	3.125
	September-November	1.384	1.009	0.438	2.813

Table 3: Analysis of variance.

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Season	1	8.490	8.490	25.069	1.62e-05***
Treatment	5	19.340	3.868	11.421	1.06e-06***
Season * Treatment	5	2.397	0.479	1.416	2.42e-01
Residuals	36	12.193	0.339		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Table 4: Pairwise comparison of all treatments.

Contrast	Estimate	Std. Error	t value	Pr(>|t|)
SFC-FCVB	1.503	0.291	5.166	0.000***
L5VB-FCVB	0.286	0.291	0.983	0.920
SL5-FCVB	1.328	0.291	4.564	0.001***
FCNB16-FCVB	1.025	0.291	3.523	0.014*
L5NB16-FCVB	1.741	0.291	5.982	0.000***
L5VB-SFC	-1.217	0.291	-4.183	0.002**
SL5-SFC	-0.175	0.291	-0.601	0.990
FCNB16-SFC	-0.478	0.291	-1.643	0.577
L5NB16-SFC	0.238	0.291	0.816	0.963
SL5-L5VB	1.042	0.291	3.582	0.012*
FCNB16-L5VB	0.739	0.291	2.540	0.140
L5NB16-L5VB	1.455	0.291	4.999	0.000***
FCNB16-SL5	-0.303	0.291	-1.042	0.900
L5NB16-SL5	0.413	0.291	1.418	0.716
L5NB16-FCNB16	0.716	0.291	2.459	0.163

findings contradict previous research from Ghana, which revealed that intercropping maize and velvet beans improved soil nutrients, resulting in higher maize yields (Du *et al*., 2018). Differences in results could be attributed to differences in velvet bean planting seasons. Velvet beans were planted at the same time as maize in this trial, but velvet beans were sown three weeks after corn in the Ghana study. Field observations revealed low ear filling and rotting of maize in plots intercropped with velvet beans.

Furthermore, maize stems were discovered bowed or lying down as a result of the high weight of velvet beans crawling on them. Over-competition lowered the number of maize plants in the same plots, lowering primary grain yields. The results of the second season (September-November) corresponded with South African research that found that when velvet beans are planted earlier in a maize-velvet bean intercropping system, velvet beans outcompete maize due to their vigor (Chakoma *et al*., 2016). Rainfall was delayed due to climate change and planting was also delayed, resulting in increased pests and illnesses and low maize yields. Most maize plants had maize streak disease, aphids and autumn armyworms, which could have reduced maize production in both seasons. Megas and Rocket pesticides were sprayed on crops to decrease pest and disease spread and unhealthy maize plants were pulled from the garden to avoid further spread to healthy crops. The above findings disagree with previous researchers who reported that velvet beans intercropping with maize before 42 days reduced the weed burden and maize yield while planting after 42 days of maize increased maize yield (Gbaraneh and Nwonuala, 2011).

Intercropping strategies benefit not just crop yields but also soil biodiversity in an agroecosystem. Intercropping maize and legumes benefit soil microorganisms, improves soil structure and boosts soil nutrients by fixing more N using nitrogen-fixing bacteria found in root nodules. Previous research has shown that intercropping maize-grass pea has the potential to boost yields in low P and moisture soils due to interspecific rhizosphere interactions in the soil ecosystem (Shuang-Guo *et al*., 2023). Intercropping maize-legume was reported to have the ability to increase Land equivalent ratio, more resources (N and PAR) utilization and had larger values of resource use efficiency *i.e*. for water, nitrogen and solar radiation (Temesgen *et al*., 2015).

CONCLUSION

Pairwise comparisons at 1% significant level, the following pairs show a very high statistical significance at a 1% significant level: SFC - FCVB (p<0.001); SL5 - FCVB (p<0,001) and L5NB16 - L5VB (p<0.001). The pairs that show statistical significance at a 10% significant level include FCNB16 - FCVB (p = 0.014); L5VB - SFC (p = 0.002) and SL5 - L5VB (p = 0.012). Both insufficient and excessive rainfall are detrimental to maize yields because they result in insect and disease infestations, which diminish crop productivity. According to the study, velvet beans should be planted three weeks after maize in intercropping systems to boost soil fertility and maize yields. Second, smallholder farmers should embrace early planting and the use of climate-resilient maize seeds to boost maize yields in the face of climatic uncertainty in the region.

ACKNOWLEDGEMENT

We gratefully appreciate the African Centre of Excellence for Climate Smart Agriculture and Biodiversity Conservation Management for the funding support they provided through the World Bank.

Conflict of interest

All authors declare no conflict of interest.

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