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Effect of selected climate smart agronomic practices on maize growth and yield

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Abstract

Maize (*Zea mays* L.) is one of the major food crops grown by majority of smallholder households in Uganda, and it serves as their main source of food and income. But over the years, maize productivity in the area has been gradually declining, especially as a result of climate variability manifested by reduced frequency of rainfall and increased temperature. Maize farmers are encouraged to use improved agronomic practices, commonly referred to as climate smart agronomic practices (CSAPs) to counteract the adverse effects of climate variability, and consequently sustain maize grain yields. However, the effects of these climate smart agronomic practices (CSAPs) as implemented by farmers on maize productivity have not yet been established. Therefore, this study was conducted to validate the effect of CSAPs on maize growth and yield. The treatments included (T1) Maize intercropped with common beans, (T2) maize planted in basins of three maize plants, (T3) maize planted in basins of two maize plants, (T4) maize planted in a plot prepared by minimum tillage, (T5) maize planted in plots mulched with dry grass, and (T6) the untreated control of monocropped maize on a conventionally prepared un-mulched plot. The treatments were laid out in a randomised complete block design with three replications, in two districts in 2019A and 2019B. Planting in basins with two plants, minimum tillage and mulching were the three CSAPs that showed superior growth and yield scores.

Key words: Intercropping, minimum tillage, mulching, planting in basins, Uganda.

Introduction

Climate variability has increased worldwide and is threatening productivity of food and fibre for ever increasing human populations in various continents (Kassie *et al*., 2014). Climate determines pattern of vegetation types and yields as well as the length of cropping seasons, any change in climate, therefore, affects crop production (Ochieng *et al*., 2016). This also affects the supply of food to the population leading to food insecurity. According to FAO (2014), climate change has been manifested by too much or too little rainfall and is likely to cause considerable crop yield losses thereby affecting farmers' livelihoods, most of whom are dependent on seasonal rainfall. In fact, it is projected that crop yield in Africa shall fall by 10-20% by 2050 due to climate change (Nwaobiala and Nottidge, 2013). Therefore, given the already existent severity of food insecurity in the African continent (World Bank, 2010), it is necessary to develop agricultural practices that include aspects that minimise the threats posed by climate change. In response is the concept of Climate Smart Agriculture (CSA), which deploys strategic agronomic practices that can buffer the variability of climatic factors that affect crop productivity (UNFCCC, 2015).

FAO (2013) indicates that CSA is any approach that addresses three pillars of food security i.e., sustainable increase in food productivity, adaptation (enhanced resilience to climate change), and mitigation (agroforestry, residue management, soil and water conservation, restoration of areas drained and degraded for crop production) (Smith *et al*., 2007). Research also shows that direct seeding under reduced-tillage, improved protective soil cover through cover crops, crop residues or mulch, crop diversification through rotations, and integrated soil fertility management (mulch, compost, crop residues and green manure with fertilisers) are important in addressing or preventing macro- and micro-nutrient deficiencies (FAO, 2013; 2014; Muzangwa *et al*., 2013; Lin, 2011). However, the adoption of Climate Smart Agronomic Practices (CSAPs) by farmers has been relatively low at a continental level despite the promising benefits that can accrue from such (FAO, 2010).

Maize, the most popular staple food for smallholder farmers in sub-Saharan Africa (SSA) is particularly affected by rainfall and temperature variability, prompting adoption of CSAPs (Knox *et al*., 2012). A number of studies have reported on the effects of CSAPs on maize productivity and yields. De-Groote *et al*. (2005) in a longitudinal study in Kenya reported that intensity of fertiliser use has a major positive effect on maize yield during moisture stress conditions. The yield-enhancing effects of fertiliser and improved maize varieties were also brought out by Onyango (2009) working in the Trans Nzoia area of Kenya, who noted that the yields vary with different improved maize varieties, fertiliser types and intensity of application, and management of agronomic practices during dry conditions. According to Cairns *et al.* (2013) incorporation of CSAPs, for instance, use of reduced tillage, legume intercrops and use of improved seeds in maize cropping system increases resilience and has significant increase in maize yield. This is in agreement with Kimaro *et al* (2016) who carried an experiment on reduced tillage, use of mulches and cover cropping and found out that

CSA practices conserve water and mineral nutrients and consistently could increase maize yield per season. Kichamu *et al.* (2021) also reported that CSAPs improve soil health, mitigate against climate variability and improve agricultural productivity. In Uganda, Zizinga *et al* (2022) indicated that CSA practices enhance agricultural production by alleviating adverse climate effects on maize productivity through improved soil moisture storage, water use efficiency, increased soil carbon sequestration and nutrient loss limitation in basins. Use of planting basins in maize production is a conservation agriculture technology that yet to be widely practiced in Uganda. This study set out to compare the planting basin technology and other well documented CSAPs on maize growth and yield.

Materials and methods

Study sites

The experiment was conducted in the Eastern region of Uganda in the two districts of Namutumba and Mayuge. These districts were selected due to their fragility to climate variability in Uganda and smallholder farmers in the area have particularly adopted CSAPs with an intention to increase maize productivity. According to UBOS (2019), Mayuge District was established in 2000 by the Act of Parliament of Uganda, it is at altitude of 1,350 m above sea level, Latitude 0°27’22.64"N, Longitude 33°28’49.4"E the total area covered by the district is 4678.22 km^2 of which 76.62% (3584.66 km^2) is water and 23.38% (1093.56 km^2) is land. The common crops grown are sugarcane, coffee, maize, banana, rice, cassava, sweet potatoes, groundnuts, beans and cabbage. Namutumba district was created by Act of the Ugandan parliament in 2005 and became operational on 1st July 2006,it is at an altitude of 1134 m above sea level, Latitude 0^0 $50^!$ 10 N, Longitude 33^0 $41^!$ 10 E, the total area covered by the district is 801.87 sq.km most of which is land. The crops grown are sugarcane, cotton and coffee, which are normally grown purely for cash; and maize, groundnuts, beans, millet, cassava, rice, sweet potatoes, soybean and, bananas grown for food.

Experimental design and set up

The experiment was laid out in a randomised complete block design (RCBD) in each of the two locations; and the treatments were replicated three times for two consecutive seasons, 2019A (first rain season) and 2019B (second rain season). The treatments were comprised of: Maize intercropped with common beans (T1), maize planted in basins with three maize plants each (T2), maize planted in basins with two maize plants each (T3), maize planted in a plot prepared by minimum tillage (T4), maize planted in plots mulched with dry grass (T5), and the untreated control of monocropped maize on a conventionally prepared un-mulched plot (T6). Longe 10H was the maize variety used and K132 was common bean variety partnered with maize in T1. Plot sizes were 7m x 7m. In the control plots, maize seeds were planted at a spacing of 75cm x 30cm. For treatments with basins, the dimensions of each basin were 35cm long x 15cm wide x 15cm deep spaced at 90 x 45cm (Otim *et al.,* 2015). For basins with three maize plants the intra-row spacing of 11.6cm used as commonly practiced by farmers, while in those of two maize plants an intra-row spacing of 17.4cm was used. In plots with basins, there were 120 basins per plot; and where there were two maize plants per basin, there was a total plant population of 240 per plot. In basins where three plants per basin, the total plant population was 360 maize plants per plot. In all the other treatments (mulched, minimum tillage, intercropped, and control) the plant population was 220 per plot.

Mulched plots were first ploughed, and a 10cm thick mulch of dry swamp grass applied before planting. Plots with minimum tillage were established by only ploughing the vegetation over the soil surface without disturbing the soil structure. In plots where intercropping was done, land was ploughed well, holes dug and maize seeds planted at 75 x 30 cm spacing. Rows of common bean (*Phaseolus vulgaris*), variety K132 were planted in between rows of maize at 30 cm intra-row spacing. A blanket application of DAP fertiliser at a rate of 10gms was added to all plots. During the growth period, weeding was done twice per season with a hand hoe to maintain a weed free environment.

Data collection

Data collection started three weeks after planting and continued fortnightly until harvest. Data was collected from ten maize plants randomly selected and tagged in each plot at the beginning of data collection. Data was collected on the following growth characteristics and yield performance traits:

1. Plant height: At every sampling interval, the heights of the ten maize plants selected were measured using a tape measure from the ground level to the uppermost fully expanded leaf following the methodology of Karuma *et al*. (2016).

2. Plant vigour: The selected plants were physically evaluated for growth vigour on a scale of; 1=Very good, 2= Good, 3=Fair, 4=Poor and 5= Very Poor; according to Trachsel *et al*. (2010).

3. Number of leaves per plant: Cumulative number of leaves formed on each plant fortnightly for the ten selected maize plants were counted and recorded.

4. Leaf area: This was determined by measuring the length of the third leaf from the top and its width at the widest middle part using a tape measure. Then, the product of the two values was multiplied by 0.71 (where 0.71 is a constant for grasses

and cereals) to give the area of one leaf which was later multiplied by the total number of functional leaves on the plant to obtain the total leaf area of the plant (Karuma *et al*., (2016).

5. Number of cobs: This was determined by physically counting the cobs harvested from each of the ten plants tagged in the whole plot and later added to obtain the mean.

6. Grain yield (g/m^2): At harvest, cobs from $2m^2$ were removed and dried to 12-13% moisture content. Cobs were then shelled and the grain weighed to determine the weight;

$$\text{Grain yield } (\text{g/m}^2) = \frac{\text{Grain yield (g)}}{\text{Area harvested } (\text{m}^2)}$$

Data analysis
All the data were subjected to analysis of variance (ANOVA) using GenStat Version 14. Treatment means for the different parameters were separated using Fisher's protected least significant difference (LSD) procedure at 0.05 level of significance.
Results

Plant height
Plant height significantly differed by the treatments studied ($P<0.05$) at the Mayuge site. The tallest plants were recorded in the plots with basins with 3 maize plants followed by those in plots with basins with two plants, and the shortest were in the untreated control (Table 1). There was no significant difference in height among maize plants under minimum tillage, mulching and intercropping treatments at this site. Results from the Namutumba site also reported significant differences in plant height among the treatments ($P<0.05$); with a similar trend in variations among treatments as the Mayuge site (Table 1). At this site, plants were relatively shorter in stature compared to the Mayuge site.

Plant vigour
Plant vigour was significantly influenced by treatments in both sites ($P<0.05$). From the Mayuge site, results indicated that the untreated control had the lowest maize plant vigour (score of 2.9 out of 5; scores 1 = highest vigour, 5 = lowest vigour) followed by plants in the intercrop of maize and beans; and the highest vigour was recorded on plants in the basins with two plants at a mean score of 1.28. Mulching, minimum tillage and basins with three maize plants treated plants showed no discernable differences in plant vigour (Table 1). In Namutumba, the trend was similar

Table 1. Effect of climate smart agronomic practices on growth characteristics and yield performance traits of maize in the two districts

District	Treatments	Plant height (cm)	Plant vigour (descending vigour on a scale of 1 to 5)	Number of leaves/ plant	Leaf area (m^2)
Mayuge	Basins with 3 maize plants	106.1^{d}	1.67^{b}	10.32^{c}	0.45^{b}
	Basins with 2 maize plants	102.6^{cd}	1.28^{a}	10.61^{d}	0.45^{b}
	Intercropping with beans	96.2^{bc}	2.05^{d}	9.71^{b}	0.45^{b}
	Minimum tillage	97.1^{bc}	1.72^{c}	9.80^{b}	0.46^{b}
	Mulching	94.2^{b}	1.72^{bc}	9.84^{b}	0.45^{b}
	Control	77.81^{a}	2.90^{e}	8.52^{a}	0.26^{a}
	Mean	95.18	1.91	9.77	0.29
	$LSD_{(0.05)}$	3.47	0.15	0.40	0.09
Namutumba	Basins with 3 maize plants	97.21^{c}	1.75^{c}	10.03^{c}	0.45^{b}
	Basins with 2 maize plants	95.09^{b}	1.24^{a}	10.52^{d}	0.46^{b}
	Intercropping	86.49^{b}	2.01^{c}	9.47^{b}	0.45^{b}
	Minimum tillage	89.61^{b}	1.71^{b}	9.59^{b}	0.43^{b}
	Mulching	87.06^{b}	1.55^{b}	9.52^{b}	0.42^{b}
	Control	73.98^{a}	2.86^{d}	7.92^{a}	0.21^{a}
	Mean	88.24	1.85	9.53	0.38
	$LSD_{(0.05)}$	4.14	0.23	0.24	0.26

Values in a column followed by different letter are significantly different at $P<0.05$. (df =5; 35)

with the notable exception of the fact that both the intercrop and basins with 3 plants per hill performed poorly in vigour, after the untreated control (Table 2).

Number of leaves per plant

Number of leaves per maize plant showed distinct differences among treatments in both sites ($P<0.05$). In the Mayuge site, plants in basins with 2 maize plants had the highest number of leaves per plant (10.61), followed by plants in the basins with 3 maize plants (10.32) and the untreated control had the lowest number of leaves (8.52). Mulching, minimum tillage, and intercropping with beans were at par in number of leaves per maize plant (Table 1). A similar trend was observed in Namutumba.

Leaf area

The leaf area measurements also showed distinct differences among treatments in both sites (P<0.05). In Mayuge, apart from the untreated control that clearly had the lowest readings, the rest of the treatments were not significantly different with respect to leaf area; this was also the case in the Namutumba site (Table 1).

Number of cobs per plant

Number of cobs per plant in the studied maize variety ranged from 1-3, and was significantly influenced by treatments in both sites (P<0.05). In the Mayuge site, basins with two maize plants had a good number of plants in the plots with 3 cobs per plant (average of 2.46) whereas plants in control plots usually had only one cob per plant (average 1.23) and the rest of the treatments had majority of the plants with two cobs (Fig. 1a). Namutumba had a similar trend with the exception of the fact that the untreated control and basins with three maize plants were not significantly different (Fig. 1b).

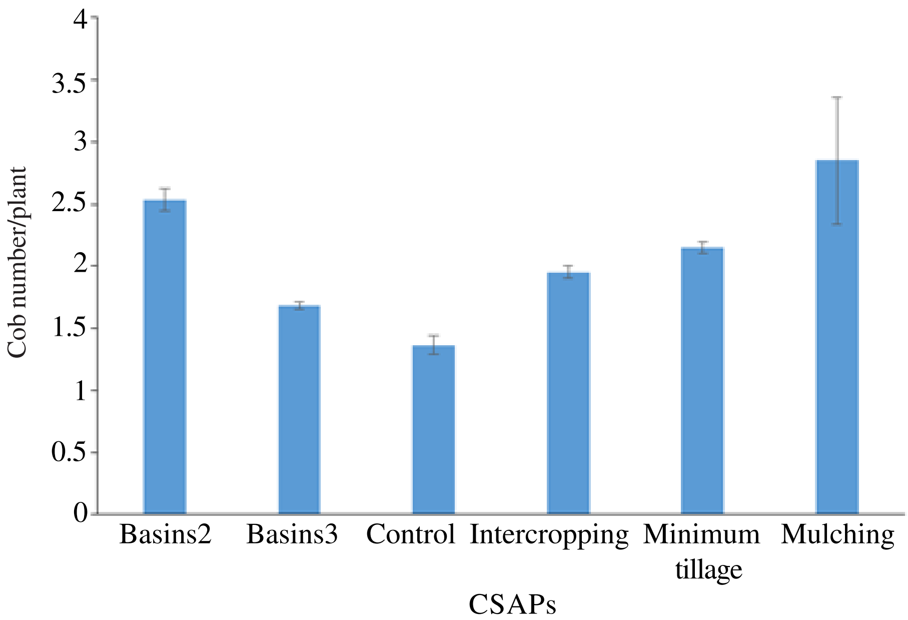

Figure 1a. Effect of treatments on cob number at the Mayuge site.

Maize grain yield in kg ha^{-1}

Maize grain yield was another trait significantly influenced by CSAP treatments (P<0.05). In Mayuge, basins with two maize plants registered the highest maize grain yield followed by minimum tillage, mulched plots, intercropping, basins with three maize plants and the untreated control plots yielded the least (Table 2). Namutumba site has relatively less yield compared to Mayuge but the trend was similar.

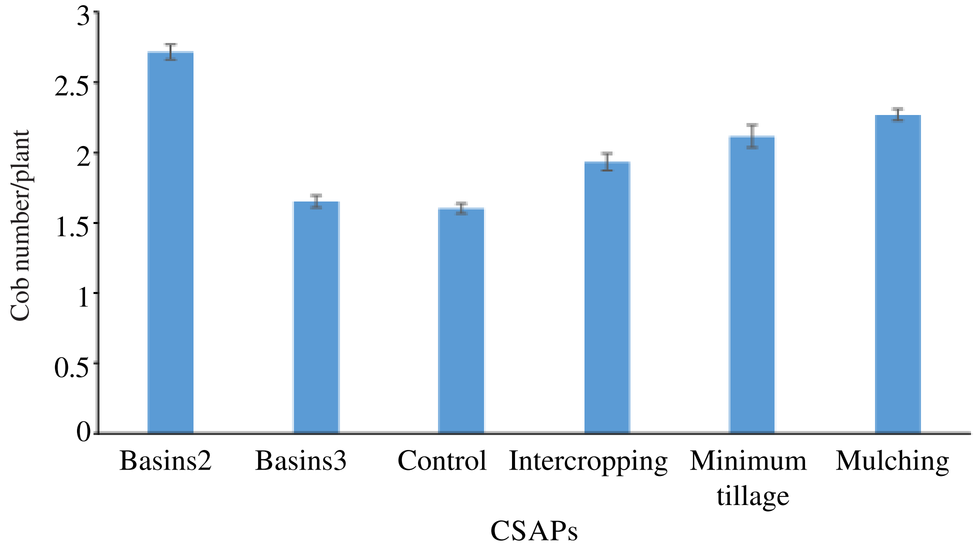

Figure 1b. Effect of treatments on cob number at the Namutumba site.

Table 2. Effect of climate smart agronomic practices on yield (g m^{-2}) of maize in the two districts

Treatments	Mayuge	Namutumba
Basins with 3 maize plants	253.5^{b}	240.5^{b}
Basins with 2 maize plants	391.7^{d}	349.5^{d}
Intercropping	269.0^{b}	219.5^{b}
Minimum Tillage	333.0^{c}	291.7^{c}
Mulching	330.2^{c}	304.2^{c}
Untreated Control	143.5^{a}	143.7^{a}
Mean	286.8	258.2
LSD $_{(0.05)}$	33.88	32.68

Discussion

Mean heights of maize plants under CSAP treatments were significantly higher than those under the untreated control treatment. Maize plants grown in the basins were taller than those of the rest of the treatments. Planting in basins is believed to conserve moisture. In the study area, Mayuge received an average annual rainfall amounts of 893.25mm while Namutumba received an average of 702.25mm for the two seasons of the year 2019. According to Matila (2021), the annual water requirements for maize is 1092.78 mm/annum. As such, practices that conserve moisture are essential.

Appropriate soil moisture promotes faster plant growth as a results of longer internodes that are appropriate for positioning flag leaves to capture sunlight (Prasad *et al.,* 2014). Basins with 3 maize plants were taller than those with two maize plants, which may have been due to competition for light in the higher population treatment. Otim *et al*. (2015) also showed moderately populated basins to perform better agronomically than higher plant population counterparts indicating an optimum threshold for benefits.

The short stature of plants in the untreated control plots may be due to the higher degree of soil disturbance and/or less/no soil cover that may have led to quick moisture loss that affected maize growth vigour and reduced cell growth and elongation of inter-nodes. According to Suriyaprabha *et al.* (2012), less availability and uptake of soil moisture by a maize plant physiologically triggers the release of silica deposits that stiffen cells and reduce cell growth consequently reducing height.

The high vigour of plants in the basins with two plants may be partly due to the better moisture, and the moderate plant populations of this treatment. The corresponding high vigour in mulched plots may be attributed to good infiltration and a micro-climate created by mulches on soil surface (Bu *et al.* 2013). The two treatments had scores of plant vigour in the range of 1–2, which according to the methodology of Trachsel *et al*. (2010) are good scores of vigour. Zhao, Liu and Zhang (2010) showed that plant vigour was a result of the combined effect of presence of soil moisture, appropriate plant population, and proper nutrient use. The low vigour in the control plots may have been a result of inadequate soil moisture due to evaporation from the bare ground. Alak *et al.* (2020) confirm that evaporation and evapotranspiration from open ploughed lands lower moisture content level from the soil and affects crop growth in such areas.

The relatively lower number of leaves in the control plots may also be explained by the exposure of soil in these plots due to over ploughing and lack of soil cover, which according to Jalilian and Delkhoshi (2014) could have caused insufficient soil moisture in vegetative stage resulting into reduced cell multiplication hence lower leaf area and fewer number of leaves.

Maize grain yield also followed the trend of CSAP plots outperforming the untreated control. Practices that conserve moisture in the crop cycle showed an increased yield advantage with a corresponding increase in number of cobs per plant. Cornelissen *et al.* (2013) attributed the advantage to availability of during the critical moisture requirement stage of maize. Morphologically, Heidari (2013) ascribed low maize yield to poor leaf performance in space and time. The status in this study showed control plants to indeed have low readings in leaf numbers and leaf area. This resulted into a smaller capacity of maize plants to photosynthetically produce assimilates to fill up the grains (Fan *et al.,* 2018).

The high grain yield performance of plots in basins with two plants point to this CSAP being optimal in utilisation of soil resources and providing a conducive environment for maize growth. The plants in this treatment were the best in plant height, vigour and number of leaves; which may have enhanced capture of sunlight, proper cell division and multiplication and production of assimilates that lead to increased crop yield (Rosenstock *et al.* (2016). Mulching and minimum tillage though not as good as the basin treatments were often not far behind especially in vigour and leaf parameters. These results again echo those of Jalilian and Delkhoshi (2014) who attributed the high yields to a corresponding right number of leaves (source) on the maize plant, which determined the cob number and yield capacity (sink) of the crop. Torres *et al.* (2011) and Wassom *et al.* (2013) had earlier indicated that a right leaf area emergence, leaf angle and ratio result into production of higher assimilates and increase yield potential of grain and cereal crops.

The study indicates better performance of CSAPs in the maize production and particularly basins, mulching, minimum tillage and intercropping. Farmers should be advised to appropriately plant the right number of maize plants per basin to achieve better results/yields. Although basin construction may seem to add labour challenges to farmers, the yield that accrue from the production gives higher return to a smallholder farmer. Minimum tillage is less laborious in its initial garden preparation but requires more intensive weeding when maize has reached the reproductive stage that requires less disturbance from anthesis to silks.

Conclusion

The results showed that planting two maize plants in a basin, applying mulch, or minimum tillage significantly increases the maize plant height, vigour and leaf area, and consequently maize grain yields.

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