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# The effect of tillage, cropping system, variety, and nitrogen fertilizer levels on maize production

Waya, A.O.[1]*, Talwana, H.[1] and Kyamanywa, S.[1]

[1]Department of Crop Science and Horticulture, Makerere University, P. O. Box 7062, Kampala, Uganda.

*Corresponding author: anduaolga@gmail.com

## Abstract

Climate variability and declining soil fertility are constraining agricultural productivity in Uganda. Climate smart agricultural practices are needed to improve the situation. The study tested four practices: cropping system, variety, tillage methods, and use of inorganic fertilizer in different combinations in factorial designs on-farm and on station. Data was taken on plant height, leaf area index (LAI), number of green leaves/ plants, number of cobs/plots, yield/plot, and stovers' dry weight. Results indicated that the only significant interaction of the factors was of variety and tillage system on plant height. Otherwise, the factors impacted the response parameters as sole entities. Longe 10H was the variety with taller plants and higher yields especially under reduced tillage. Maize monocrop had the most green leaves throughout the season but lower values of leaf area index than the intercrops; maize in the intercrop also had more cobs and yield per plot. Application of N brought about significant responses for all growth and yield parameters. The application of N fertilizer at the rate 60 kg $ha^{-1}$ (100% recommended) and above significantly improved all growth and yield parameters. Solely, Longe 10H maize variety produced more yield than Kawanda. Therefore, a strategy including maize variety Longe 10 H variety intercropped with beans under reduced tillage, and given 60 kg $ha^{-1}$ N fertilizer a season can be used as a CSA practice to sustainably increase maize productivity.

Key words: Climate smart agriculture, intercropping, nitrogen fertilizer, reduced tillage, Uganda

## Introduction

Maize (*Zea mays*) is one of the major staples and most widely cultivated crops in Uganda, particularly in eastern Uganda, grown for its food security and economic value. Maize is consumed as roasted or boiled corn on the cob, maize meal called posho, porridge, or fermented into alcohol or dough. The crop is produced primarily by small-scale farmers (90%), who depend on agriculture for their livelihood (Agona *et al*., 2014), and have a low capacity to withstand risk (Abegunde *et al*., 2019; Awazi *et al*., 2021). Despite its huge contribution to the national economy, yields of maize in Uganda have remained low. The current average maize yields range from 1.7- 2.5 $tonha^{-1}$, which is far below the potential 5-7.5 $tonha^{-1}$ (Lee, 2020; Midamba *et al.*, 2025). The low productivity is attributed to climate variability, low adoption of improved varieties, high pressure from pests and diseases, low soil fertility, inappropriate tillage practices, minimal use of fertilizers, poor knowledge on crop management and post-harvest management, among others (Chemura *et al*., 2025; Epule *et al*., 2021; Kaizzi *et al*., 2012).

The current maize farming systems are rain fed, and are vulnerable to rain and temperature variations (Thornton *et al*., 2014) with consequent impacts on soil moisture content, leading to either reduced yields or total crop failure (Mubiru *et al*., 2012, 2018). Such effects are expected to extremely affect smallholder farmers that depend on agriculture, and are least equipped to cope with climatic hazards (Babatolu and Akinnubi, 2016). To reduce vulnerability to climate variability and change, there is need for innovative approaches for managing climate risks while also strengthening the farmers adaptive capacity, and building resilience to ensure food security (Zougmoré *et al*., 2018). More so, as the population in Uganda is growing at 3.2 percent per annum (UBOS, 2024), an increase of about 1 million "new mouths" to feed per year (Epule *et al*., 2021). The neighboring countries of the Democratic Republic of Congo and South Sudan also depend on maize from Uganda for food security (Daly *et al*., 2017). These dynamics require an increase in agricultural production of 50% by 2050 in order to provide enough food (Molotoks *et al*., 2021).

There is an urgent need for solutions to address the challenges resulting from climate variability, declining soil fertility, and inadequate access to new technologies to boost productivity. One option is the use of climate smart agricultural practices (CSA).

Climate smart agriculture has the core pillars of increasing agricultural productivity and incomes, adapting to climate change, and reducing greenhouse gas emissions (Kabato *et al.*, 2025; Ma and Rahut, 2024; Mazumder, 2024; Zakaria, 2023). These three pillars are interconnected and can create positive synergies, but also potentially lead to trade-offs (Colozza *et al.,* 2025; Tesema and Mekoya, 2025). Therefore, careful planning is needed to maximize synergies and minimize negative impacts. For example, despite the reported positives that accrue from adoption of CSA practices such as use of inorganic fertilizer, appropriate varieties, intercropping, and minimum or reduced tillage practices (Assaye *et al*., 2025; Jat *et al*., 2024) there is yet no optimized production systems through which CSA practices can be harnessed to improve growth conditions and produce higher yields. Intercropping has been reported to contribute to enhancing land productivity and stabilizing crop yields in the face of climate variability (Himanen *et al*., 2016), reduced tillage sustains soil moisture retention and mitigation of intra-seasonal dry spells in addition to reducing soil erosion (Asmamaw, 2014; Mbanyele *et al*., 2021; Mugalavai, 2025), while application of inorganic fertilizers enhances plant growth, development and yield (Ike *et al*., 2013 ; Ye *et al*., 2020). However, these practices have not been adequately studied together to assess synergies and interactions in maize systems in Uganda. Therefore, this study was conducted to determine the effect of combining cropping system, variety, fertilizer application, and tillage for increased maize productivity in drought prone agro-ecologies of Uganda.

## Materials and methods

*Study area*

Field experiments were carried out at two sites in eastern Uganda in the central agro-ecological zone for three consecutive seasons in 2018 and 2019 (first and second cropping seasons of 2018 and first cropping season of 2019). An on-farm experiment was conducted on a farmer's field in Namutumba district located at latitude 00°502 063 N and longitude 33°412 063 E; while an on-station experiment was conducted in Mayuge district at Ikulwe Satellite Station located at latitude 0º27'3"N and longitude 33º28'16" E. The two districts are documented to be vulnerable to extreme climate variability and to experience frequent of extreme weather events (Muhangi *et al*, 2022; Bamweyana *et al*., 2023; Bagamba *et al*., 2025). The Namutumba site has a mean daily temperature range of 16 to 35°C with an average annual rainfall between 900 and 1,150 mm. The Mayuge site has a mean daily temperature range of 17 to 30ºC and an average annual rainfall of 1,297 mm. The soils types in both experimental sites are predominantly Oxisols, an attribute associated with high water/nutrient infiltration (Kassam *et al*., 2014; Ribeiro de Jesuz and Ferreira, 2022; Oliveira *et al*., 2025). The two experimental sites receive a bimodal rainfall pattern with the first rains occurring from March to June, and the second from August to November, hence two cropping seasons per year.

*Experimental design*

Study 1. In the on-farm experiment, the treatments comprised of 3 factors: cropping system (at three levels: maize monocrop, intercrop in single (1:1), and double (1:2) arrangements); two maize varieties (Hybrid Longe 10 H and Kawanda); and two tillage methods (reduced (RT) and conventional (CT)) in a 3x2x2 split-split randomized complete block design (RCBD) with three replications. The experimental fields were ploughed and harrowed using an ox-plough for conventional tillage; and with hand hoe to a depth of 3-4 cm for reduced tillage (minimum soil disturbance, i.e. the crop residues were left on the field for moisture retention). The plots were marked before planting. Each treatment was applied in a plot area measuring 4m x 9m (36m$^2$) leaving a pathway measuring 1 meter between plots and 2 meters between blocks. The test varieties were longe10 H variety, which was chosen due to its high productivity and drought tolerance potentials, and Kawanda, the farmers' preferred improved variety, for its high yielding and drought tolerance traits. Bean variety K132 was intercropped with maize as the test crop because of its short maturity, drought tolerant and high yielding variety (David *et al*., 2000). Two maize seeds were planted per hill at a spacing of 90 cm between rows and 30 cm between the plants. The maize plants were thinned to one plant per hill two weeks after emergence. Bean seeds were planted in between rows of maize in an additive manner at an interplant spacing of 30 cm. No fertilizer was applied to represent farmers' practices in this area. Other agronomic management practices such as manual weeding was the same for all the plots (treatments).

Study 2. The treatments in the 3 factorial on-station experiment consisted of cropping system (at two levels: monocrop and intercropping (single 1:1), five levels of N fertilizer rates (0, 50%, 75%, 100% and 125%), and two tillage systems (conventional and reduced). The decision to apply a higher N fertilizer rate (125%) above the recommended optimum (100%) followed a previous study by Kandil (2013) which established that higher maize yields can still be realized even when the recommended rate is exceeded. The experiments were arranged in a split-split plot design and laid out in a randomized complete block design (RCBD) with three replications. The experimental field were ploughed using a tractor (primary and secondary disc were used) for conventional tillage; and for reduced tillage plots (minimum soil disturbance) were prepared as in study 1. The plots demarcations, planting and spacing was done as in study 1. For the maize plots that received mineral fertilizer treatments, the total amount of nitrogen fertilizer (Urea, 46% N), were applied at the rate of 60 kg ha$^{-1}$ as a recommended dose (benchmarked at 100%), and the rest calculated accordingly. The N fertilizer was applied in two equal splits, one at planting and the remaining N was top-dressed at 45 days after planting, when the plants started to grow rapidly and N demand was high. This was done for all treatments requiring nitrogen fertilizer. Weeding and other agronomic procedures were as in study 1. The experiments at both sites were rain fed.

*Data collection*

*Growth parameters*

Data on plant height, number of green leaf and leaf area index (LAI) was collected on 3 tagged maize plants per plot. Tagging was done by random selection of 3 maize plants per plot from the net plot area of 4 m x 9 m (36 $m^2$) at different growth stages i.e. 45, 60 and 70 days after planting, representing V10, V15 and R1 stages of maize growth, respectively, throughout the season. Plant height for all the treatments in each replication was taken using a measuring tape from the ground surface to the highest tip of the canopy at each growth stage. The total number of leaves were counted on the 3 tagged plants from 45DAP to anthesis; while the number of green leaves were counted per plant to physiological maturity following the protocol of Gungula *et al*. (2005). The maize leaf area was estimated by the length and maximum width of the third leaf of 3 tagged plants in each treatment using measuring tape. Leaf area was obtained using the following formula: Leaf area = Leaf length x Leaf width x 0.75 as prescribed by Amanullah *et al*. (2009). Then, LAI was computed by dividing the total leaf area of a maize plant stand by the total land area occupied by a single stand as recommended by Karuma *et al*. (2016).

*Yield*

Harvesting was done manually at the ground level using a panga when the maize had reached physiological maturity. The whole plot was hand harvested for yield inventory. To determine the maize stover's fresh weight yield (g) (above ground biomass), samples of 3 plants per plot were selected randomly and weighed in the field. The number of cobs per plot in each treatment were recorded. This was followed by oven drying at 60°C for 72 hours to a constant weight. The final weight was recorded using an electronic weighing scale (Jesma, Vejle, Denmark).

*Statistical analysis*

The data were pooled over seasons and analyzed using the General Linear Model Procedure of GenStat for a split-split plot design, $14^{th}$ Edition, to determine the effect of the studied factors on plant growth and yield parameters; this was done separately for the growth stages of 45, 60 and 70 (tasselling) days after planting (DAP). Means of the dependent variables of plant height, LAI, number of green leaves/plants, number of cobs/plots, stover's yield (g) and yield/plot/kg) were separated using Fischer's LSD test at 0.05 probability level.

## Results

*Plant growth and yield response to combinations of tillage system, cropping system and variety on-farm in Namutumba*

The on-farm results of the combined ANOVA showed that the only significant interaction of the studied factors on maize growth and yield was that of variety*tillage system on plant height at 60 DAP; and all the other two-way or three-way interactions were not significant (P>0.05; Table 1).

Individually, variety significantly influenced plant height, leaf area index, and number of green leaves/plants for most of the growth season, most especially at 60 DAP. Variety also significantly influenced grain yield per plot (P<0.01) and number of cobs per plot (P<0.05; Table 1). On the other hand, cropping system only had a significant influence on leaf area index at 45 DAP and on number of green leaves per plant at 60 DAP (Table 1). Tillage system only influenced leaf area index at the tasseling stage of maize, but interacted significantly with variety to influence plant height at 60 DAP (P<0.01; Table 1).

Variety Longe 10H plants were generally taller than those of the farmers Kawanda variety except under conventional tillage system at 60DAP where Kawanda plants were taller (Table 2). The plant height of Kawanda in the two tillage systems did not vary much; but for Longe 10H reduced tillage system had taller plants (167 cm) compared to conventional tillage (153.1 cm) (Table 2). Plant height increased through to the tasseling stage (Table 2).

The results of the effect of cropping system on leaf area index showed that intercropping maize with bean produced plants with a bigger leaf area index than those of mono crops at 45 DAP but these differences were not apparent later in the season (Table 3). Conversely, the number of green leaves per plant were more in the monocrop when compared to the intercrops especially at 60 DAP (Table 3).

The results on yield indicate that Longe 10 H performed well in terms of grain yield per plot and had higher numbers of cobs per plot (107) compared to Kawanda (96) (Table 4).

*Plant growth and yield response to combinations of tillage system, cropping system and nitrogen fertilizer application rate on-station at Ikulwe (Mayuge)*

In this site, results of the combined ANOVA indicate that there were no significant two-way or three-way factor interaction effects on maize growth and yield (P> 0.05; Table 5). Individually, fertilizer application rates significantly influenced all maize growth parameters throughout the season, as well as yield parameters (Table 5). Nitrogen

Table 1. Mean squares of maize growth and yield parameters as affected by tillage, cropping systems and variety on-farm in Namutumba pooled over seasons

| Variables | | Plant height(cm) | | | LAI | | | No. of green leaves/plant | | | Yield | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | Df | 45 DAP | 60 DAP | Tasseling | 45 DAP | 60 DAP | Tasseling | 45 DAP | 60 DAP | Tasseling | Yield/ plot/kg | No. cobs/ plot | Stover dry weight (g) |
| Reps | 2 | 530 | 32253 | 13433 | 4.0992 | 2.4313 | 12.5825 | 1.781 | 0.392 | 3.768 | 228.24 | 7693 | 11223 |
| TS | 1 | 600 | 9184 | 6119 | 0.3186 | 0.037 | 1.2114*** | 2.966 | 5.188 | 0.062 | 27.69 | 1838 | 3127 |
| CS | 2 | 613 | 4253 | 5719 | 3.2034* | 0.0017 | 1.8326 | 0.346 | 9.818** | 1.749 | 94.06 | 2837 | 31934 |
| V | 1 | 1980* | 10643* | 26146** | 6.1394* | 3.122* | 0.0908 | 2.966 | 11.485** | 5.836 | 231.91** | 3218* | 11973 |
| TS x CS | 2 | 264 | 1489 | 3647 | 0.3537 | 0.2368 | 2.0119 | 0.086 | 1.725 | 1.749 | 37.42 | 270 | 11914 |
| TS x V | 1 | 579 | 14280** | 1277 | 0.1272 | 0.6489 | 0.3941 | 2.25 | 2.25 | 0.562 | 0.29 | 488 | 17255 |
| CS x V | 2 | 278 | 902 | 2121 | 1.3054 | 0.4146 | 4.4254 | 1.568 | 2.225 | 5.025 | 18.35 | 2089 | 142 |
| TS x CS x V | 2 | 282 | 938 | 687 | 0.4904 | 0.1884 | 1.4968 | 0.481 | 1.009 | 2.332 | 48.31 | 579 | 4199 |
| Residual | 12 | 424 | 1251 | 2704 | 0.8242 | 0.5955 | 1.6887 | 1.571 | 1.136 | 2.956 | 20.65 | 700 | 5399 |

Df = Degrees of freedom, LAI = leaf area index, DAP = Days after planting, TS = Tillage System, CS = Cropping system, V = Varieties, * = Significant at $P<0.05$, ** = significant at $P<0.01$, *** = significant at $P<0.001$and values without stars are not significant

Table 2. Effect of variety and tillage system on maize plant height (cm) at different growth stages on-farm in Namutumba

| Tillage system | Variety | Maize growth stage | | | Mean |
|---|---|---|---|---|---|
| | | 45 DAP | 60 DAP | At tasseling | |
| Conventional tillage | Kawanda | 82.4 | 160 | 202.4 | 148.3 |
| | Longe10 H | 84.7 | 158.2 | 216.4 | 153.1 |
| Reduced tillage | Kawanda | 82.4 | 157.3 | 207.1 | 148.9 |
| | Longe10 H | 90.0 | 182.1 | 220.9 | 167.0 |
| Mean | | 84.9 | 164.4 | 213.7 | 154.33 |
| l.s.d | | 5.7* | 10.7* | 26.0** | |

* = Significant at P<0.05, ** = significant at P<0.01, l.s.d = least significant difference, DAP = Days after planting, l.s.d = least significant differences

Table 3. Effect of Cropping Systems on Leaf area index and Number of green leaves/plant at different growth stages on-farm in Namutumba

| Variable | Maize growth stage | | | Mean |
|---|---|---|---|---|
| | 45 DAP | 60 DAP | At tasseling | |
| *Leaf area index* | | | | |
| Intercrop 1:1 | 1.71 | 2.04 | 1.97 | 1.91 |
| Intercrop 1:2 | 1.79 | 2.04 | 1.97 | 1.93 |
| Mono crop | 1.46 | 2.03 | 1.74 | 1.74 |
| Mean | 1.65 | 2.04 | 1.89 | 1.86 |
| l.s.d | 0.27* | 0.30ns | 0.44ns | |
| *Number of green leaves/plant* | | | | |
| Intercrop 1:1 | 8.9 | 9.85 | 11.29 | 10.01 |
| Intercrop 1:2 | 8.97 | 9.58 | 11.38 | 9.98 |
| Monocrop | 9.01 | 10.19 | 11.54 | 10.25 |
| Mean | 8.96 | 9.87 | 11.40 | 10.08 |
| l.s.d | 0.82ns | 0.33** | 0.78ns | |

*= Significant at P<0.05, ** = significant at P<0.01, l.s.d = least significant difference; ns = not significant, DAP = Days after planting, l.s.d = least significant differences

Table 4. The effect of variety on maize yield across seasons on -farm in Namutumba

| Variety | Grain yield/plot/kg | No. of cobs/plot |
|---|---|---|
| Kawanda | 9.27 | 95.9 |
| Longe10 H | 12.2 | 106.8 |
| Mean | 10.7 | 101.4 |
| l.s.d | 1.91** | 11.1* |

* = Significant at P<0.05, ** = significant at P<0.01, l.s.d = least significant difference

fertilizer application influenced maize plant height at 45 DAP (P<0.001), at 60 DAP (P<0.01) and at tasseling stage at (P< 0.05). Nitrogen fertilizer application rates also had a significant influence on the number of green leaves per plant at 60 DAP and tasseling (p<0.05, and p <0.01, respectively). N fertilizer application rates significantly affected LAI at 45 DAP (p <0.05) and at tasseling stage (p <0.01). Cropping system had a significant effect on maize plant height only early in the season at 45 DAP (p<0.05) (Table 5); and cropping system only had a significant influence on the number of green leaves per plant mid-season at tasseling) (P <0.05; Table 5). At this site, tillage did not influence maize growth parameters (Table 5).

With regard to N fertilizer application levels, the rate of 100% i.e., (at 60 kg $ha^{-1}$), which is the recommended fertilizer rate, had the tallest plant at all growth stages (mean of 209.1 cm), and the untreated control (0) had the shortest plants (mean of 193.4 cm) (Table 6). Maximum maize plant height was recorded at the100% rate. The maize plants fertilized with 125% rate had plants with the highest number of green leaves per plant (mean of 12.09) followed closely by those of 100% (mean of 12.01), and the non-fertilized treatment (0) had the least (11.57) (Table 6). Again, N fertilizer application rates of 125% and 100 % recorded the highest LAI (mean of 3.00 and 2.88, respectively), and the lowest LAI (mean of 2.57) was recorded under 0 fertilizer rate (Table 6).

Maize plants in the intercrop system were taller than those in the monocrop at 45DAP; but this trend did not hold for 60 DAP and tasseling, though it held overall (Table 7). Cropping system had no influence on LAI at all maize growth stages (Table 7). On the other hand, the maize monocrop system produced a higher number of green leaves compared to intercrop system at 60 DAP and overall (Table 7).

With regard to yield parameters, results showed that individually, N fertilizer application significantly influenced all the measured maize yield parameters (P<0.05); cropping system only influenced cob yield, and tillage only influenced grain yield per plot (Table

Table 5. Mean squares of growth and yield parameters of maize as affected by tillage, cropping systems and N fertilizer application rate at Ikulwe station pooled over seasons

| Variable | | Plant height (cm) | | | LAI | | | No. of green leaves/plant | | | Yield | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | Df | 45 DAP | 60 DAP | Tasseling | 45 DAP | 60 DAP | Tasseling | 45 DAP | 60 DAP | Tasseling | Maize yield/ plot | Number of cobs/ plot | Stover dry weight (g) |
| Reps | 2 | 523 | 2736 | 4679 | 1.643 | 2.532 | 16.4545 | 0.172 | 0.156 | 11.356 | 311.45 | 1957 | 96692 |
| TS | 1 | 42 | 64.1 | 1464 | 1.678 | 2.028 | 0.1616 | 0.417 | 0.002 | 0.817 | 114.88* | 2365.3 | 7104 |
| CS | 1 | 2053* | 1480.1 | 780 | 5.488 | 3.361 | 1.5398 | 0.817 | 2.817 | 2.535* | 94.44* | 4945.5* | 11182 |
| FD | 4 | 5949*** | 3208.8** | 4926* | 3.689* | 1.156 | 4.8776** | 3.349 | 5.486* | 7.44** | 85.64* | 419.8 | 25195* |
| TS x CS | 1 | 27 | 544 | 696 | 0.174 | 1.283 | 0.2632 | 2.269 | 0.313 | 0.817 | 6.04 | 148.5 | 850 |
| TS x FD | 4 | 156 | 180.3 | 659 | 0.701 | 1.183 | 2.2078 | 1.782 | 0.96 | 1.256 | 11.75 | 288.7 | 5558 |
| CS x FD | 4 | 112 | 962.2 | 94 | 0.29 | 2.263 | 1.759 | 1.673 | 1.729 | 0.494 | 24.27 | 229.2 | 1514 |
| TS x CS x FD | 4 | 161 | 897.6 | 708 | 0.669 | 1.083 | 1.1384 | 3.162 | 3.669 | 0.71 | 21.6 | 506.5 | 11486 |
| Residual | 32 | 315 | 779.3 | 1768 | 0.925 | 1.098 | 0.9855 | 1.826 | 1.793 | 1.682 | 25.66 | 443.2 | 6328 |

Df = Degrees of freedom, LAI = leaf area index, DAP=Days after planting, TS=Tillage System, CS= Cropping system, FD= Fertilizer dose, * = Significant at $P<0.05$, ** = significant at $P<0.01$, *** = significant at $P<0.001$and values without stars are not significant

Table 6. The effect of N fertilizer application rate on maize growth parameters at different stages across seasons at Ikulwe station

| Variable | 45 DAP | 60 DAP | At tasseling | Mean |
|---|---|---|---|---|
| *Plant height (cm)* | | | | |
| 0 | 124.0 | 216.9 | 239.2 | 193.4 |
| 50 | 134.3 | 218.6 | 239.4 | 197.4 |
| 75 | 138.8 | 225.3 | 242.4 | 202.2 |
| 100 | 144.1 | 230.5 | 252.6 | 209.1 |
| 125 | 134.6 | 223.5 | 252.3 | 203.5 |
| Mean | 135.16 | 222.96 | 245.18 | 201.12 |
| l.s.d | 4.92*** | 7.74** | 11.65* | |
| *Number of green leaves/plant* | | | | |
| 0 | 10.59 | 12.19 | 11.93 | 11.57 |
| 50 | 10.75 | 12.44 | 12.07 | 11.75 |
| 75 | 10.69 | 12.58 | 12.33 | 11.87 |
| 100 | 11.03 | 12.69 | 12.32 | 12.01 |
| 125 | 10.92 | 12.75 | 12.6 | 12.09 |
| Mean | 10.80 | 12.53 | 12.25 | 11.86 |
| l.s.d | 0.37ns | 0.37* | 0.36** | |
| *Leaf area index* | | | | |
| 0 | 2.27 | 2.71 | 2.74 | 2.57 |
| 50 | 2.36 | 2.86 | 2.9 | 2.71 |
| 75 | 2.47 | 2.91 | 2.93 | 2.77 |
| 100 | 2.55 | 2.91 | 3.18 | 2.88 |
| 125 | 2.75 | 2.99 | 3.25 | 3.0 |
| Mean | 2.5 | 2.9 | 3.0 | 2.8 |
| l.s.d | 0.27* | 0.29ns | 0.28** | |

* = Significant at P<0.05, ** = significant at P<0.01, *** = significant at P<0.001, ns = not significant, DAP=Days after planting, l.s.d = least significant differences

8). N fertilizer rates of 125% recorded the highest yield at 23.1 kg/plot followed by that of and 100% at 22.8 kg of maize per plot, and 0 N fertilizer rate had the lowest at 19.30 kg/plot. The number of cobs per plot and stover's yield also followed the same trend (Table 8). The highest number of cobs (91) was obtained from 125% N fertilizer dose while the lowest (82) was recorded from the plot without N fertilizer dose. The conventional tillage system produced more grain yield per plot (22.29 kg/plot) compared to reduced tillage system (20.69 kg/plot). Intercropped maize

Table 7. The effect of cropping system on maize growth parameters at different stages across seasons at Ikulwe station

| Variable | 45 DAP | 60 DAP | At tasseling | Mean |
|---|---|---|---|---|
| *Plant height (cm)* | | | | |
| Intercrop (1:1) | 137.1 | 224.6 | 246.4 | 202.7 |
| Monocrop | 133.2 | 221.3 | 244.0 | 199.5 |
| Mean | 135.15 | 222.95 | 245.2 | 201.1 |
| l.s.d | 3.18* | 5.09ns | 8.49ns | |
| *Number of green leaves/plant* | | | | |
| Intercrop (1:1) | 10.76 | 12.46 | 12.18 | 11.80 |
| Monocrop | 10.83 | 12.60 | 12.32 | 11.92 |
| Mean | 10.80 | 12.53 | 12.25 | 11.86 |
| l.s.d | 0.22ns | 0.47ns | 0.12* | |
| *Leaf area index* | | | | |
| Intercrop (1:1) | 2.58 | 2.95 | 3.05 | 2.86 |
| Monocrop | 2.38 | 2.80 | 2.95 | 2.71 |
| Mean | 2.48 | 2.88 | 3.0 | 2.79 |
| l.s.d | 0.27ns | 0.28ns | 0.46ns | |

* = Significant at P<0.05, ** = significant at P<0.01, ns = not significant, DAP = Days after planting, l.s.d = least significant differences

produced a higher mean grain yields per plot (22.21 kg) than mono crop (20.76 kg) (Table 8). Intercropped maize produced a higher number of maize cobs per plot (92) compared to monocrop maize (82) (Table 8). This result indicates that conventional tillage, intercropping system and appropriate N fertilizer application rates improved maize yield.

## Discussion

*Plant growth and yield response to combination of variety, tillage, and cropping systems on-farm*

Maize plant height differed by variety with Longe 10 H producing taller plants compared to Kawanda. This differential response by varieties may be explained by heterosis. Maize hybrids exhibit superior performance compared to local maize varieties because of the derivational growth attributes from crosses between lines from different heterotic groups (Mogesse and Zeleke, 2022).

Table 8. The effect of N fertilizer application rate, tillage system, and cropping system on maize yield parameters across seasons at Ikulwe station

| Variable | Grain yield/kg/plot | No. of cobs/plot | Stover's dry weight |
|---|---|---|---|
| *N fertilizer (urea) %* | | | |
| 0 | 19.30 | 81.9 | 400 |
| 50 | 20.82 | 85.8 | 417 |
| 75 | 21.43 | 86.5 | 449 |
| 100 | 22.77 | 88.7 | 468 |
| 125 | 23.12 | 91.0 | 429 |
| Mean | 21.5 | 86.8 | 432.6 |
| l.s.d | 2.43* | 10.11ns | 38.20* |
| *Tillage system* | | | |
| CT | 22.29 | 90.4 | 439 |
| RT | 20.69 | 83.2 | 426 |
| Mean | 21.5 | 86.8 | 432.5 |
| l.s.d | 1.53* | 11.86ns | 58.70ns |
| *Cropping system* | | | |
| Intercrop | 22.21 | 92.0 | 425 |
| Mono crop | 20.76 | 81.6 | 440 |
| Mean | 21.5 | 86.8 | 432.5 |
| l.s.d | 0.871* | 6.52* | 23.70ns |

* = Significant at P<0.05, ns = not significant, CT= Conventional tillage, RT= Reduced tillage, l.s.d = least significant differences

Longe 10H had the highest LAI than Kawanda. This difference could be attributed to the differences in genetic constitution of the tested varieties and their differential response to climate variability shocks, confirming the observation of Waldman *et al.* (2017) that hybrid varieties *have* different maturation periods which increase their potential to adapt to the effects of increasingly erratic growing seasons. LAI could have also been influenced by genotypic differences which echoes the findings of Fei *et al*. ( 2022) that hybrid maize has a complex plant architecture compared to the local breeds. Further, the difference in LAI could be attributed to the 'Stay Green' traits of Longe 10H that led to extended vegetative growth after its companion crop was harvested. This result concurs with Szulc *et al.* (2011) and Peng *et al*. (2021) who confirmed that hybrid maize has high water use efficiency which enables it to cope with variability of meteorological conditions. Longe 10 H also had the higher number of green leaves than Kawanda. Gungula *et al*. (2005) also reported differences among varieties and attributed it to the genetic potentials of maize varieties, which causes them to utilize the applied N differently and consequently, the number of leaves produced and maintained.

Maize yield per plot and number of cobs per plot significantly differed by variety. The difference could be attributed to the high productivity potentials of Longe10H. FAO (2017) reports that compared to the local maize varieties whose average yield is normally between 400 – 600 kg/acre, under good management, Longe 10H can yield up to 3,600 kg/acre. Further, Longe 10H has high drought tolerance potentials and is less vulnerable to pests and disease attack than local varieties such as Kawanda. Mastenbroek *et al*. (2024) reported that Longe 10H (hybrid) is less susceptible to droughts, pests and diseases compared to local varieties. This result agrees with Yadav *et al.* (2025) that maize hybrids have potential of giving a 25-30% extra grain yield compared to better local and open pollinated varieties (OPVs).

Intercropping maize with beans produced plants with a bigger leaf area index than those of mono crops but only early in the season. This result is in line with the findings of Matusso *et al*. (2014) who reported that intercropped maize has high potential for light interception over sole crops. Much is it common for competition for growth resources such as sunlight, water and nutrients to occur under intercrop arrangement, leading to a possible drop in LAI, in this study, the intercrop arrangement had a higher LAI compared to monocrop. This could have happened because maize and beans have different growth resource requirements. Also, the higher LAI may be attributed to the growth resources (mainly Nitrogen) provided by beans in the intercrop. This result resonates with the findings of Anyoni *et al*. (2023) that maize intercropped with legumes produces higher LAI than sole maize crop.

Maize grown under reduced tillage system produced higher LAI than conventional tillage at tasseling stage. This could have occurred due to the high ability of roots of maize plants under reduced tillage to ably explore the soil ecosystem enabling them to tap soil moisture which prolongs crop growth duration, delays leaf senescence and improves the LAI. This result aligns with that of Sun *et al*. (2018) that maize in reduced tillage produces high LAI because subsoil tillage practices improve the content of water and nutrient in soil. Besides LAI, tillage system interacted with maize variety to influence maize plant height at 60 DAP. This could have been influenced by improved moisture conservation and availability of nutrients from decomposing crop residues, consequently resulting in sustained vegetative growth. This result confirms the observation of Karuma *et al*. (2016) that variation in maize vegetative growth occurs due to the ability of the plant roots potential to tap soil moisture.

*Plant growth parameters and yield components response to tillage, cropping systems and nitrogen fertilizer application rates on-station*

Results from on-station revealed that plant height of maize was affected by cropping system and N fertilizer application rates. The maximum plant height was recorded in the recommended (optimum) N fertilizer rate (60 kg $ha^{-1}$). These results confirm the findings of Tamele *et al.* (2020) who stated that N fertilizer promotes plant growth, increases the number and length of internodes and consequently, plant height. Previous studies (such as Amanullah *et al*., 2009; Dawadi and Sah, 2012 ) have reported that an increase in growth of maize results from nitrogen effects due to increased cell expansion, cell division and size.

The maize plants in the intercropping system were taller than those in monocrop, confirming results of the on-farm experiment. This variation could be attributed to the fluctuation in the amount and distribution of rainfall in a cropping season The result concurs with Sher *et al.* (2018) who stated that plant height and internode length increase with increasing plant population due to competition for light. Further, taller maize plants in the intercropping system could be explained by the ability of maize plants to effectively use the available resources (e.g. water, light and nutrients). This result confirms the observation of Meena *et al*. (2025) that maize in legume-based system grow luxuriantly because of better weed-suppression and enhanced soil fertility. The soil fertility, accrues from N fertilization by the legumes which promotes plant growth and development.

The number of green leaves produced per plant were affected by N fertilizer rates and increased with increasing N fertilizer rate. This could possibly be due to the readily available plant nutrients introduced by the inorganic fertilizer over a short period. The result concurs with Sandhya Rani *et al*. (2022) and is affirmed further by Tanga *et al*. (2022) that whenever maize plants are treated with high fertilizer rates, they produce a high number of green leaves. However, there was a noticeable decrease in the number of green leaves/plants irrespective of N fertilizer levels at tasseling stage. This could be attributed to senescence and abscission of lower leaves which is associated with maize at maturity stage. This result agrees with Koyama (2018) that young maize plants have more green leaves than fully matured plants because young leaves are able to import nutrients from source organs and, utilize them into their own metabolism than fully grown leaves. As a result, young leaves are guarded against premature senescence compared to fully grown ones.

The observed effects of N fertilizer application rates on LAI revealed a high mean under the highest N fertilizer rate (125%). At this rate, the maize plants could have utilized adequate nutrients provided by the excess amount above the optimum rate that compensated for losses to volatilization and leaching. This result is in line with Kandil (2013) who recorded a high LAI after applying the highest N fertilizer application. Equally, the finding rhymes the observation of Amanullah *et al*. (2007) who noted that Leaf area and LAI will increase at highest N rates. At such rates, there is increased LAI because of delayed leaf senescence, sustained leaf photosynthesis and maintenance of leaf area duration ('stay-green'). Application of the highest N fertilizer rate however, might not be feasible for smallholder farmers in Mayuge and Namutumba because of the associated financial implications.

Grain yield per plot was affected by N fertilizer rate and cropping system. The recommended (100%) and above recommended (125%) N fertilizer application rates led to high grain yield per plot. The yield due to increasing rate of N fertilizer might be related to the effective use of N fertilizer by the crop with minimal losses. Further, the grain yield under increasing levels of N fertilizer could be attributed to better utilization of nutrients by the maize plants which allowed them to grow vigorously. This result is in line with Kandil (2013) who observed that increasing level of N fertilization leads to increased grain yield and yield components of maize plants. Further, Atnafu *et al*. (2021) reported that adequate supply of N leads to a significant increase in the grain yield and its components.

The stover's dry weight increased with of the optimum N fertilizer rate. This could have been caused by accumulation of assimilates leading to increase in maize plant biomass. The result agrees with Abouziena *et al*. (2007) that, biomass increases with increasing N rates. Similarly, Dawadi and Sah (2012) and Kaizzi *et al*. (2012) confirmed that Stover's yield increased with increase in nitrogen rates.

The highest mean grain yield was recorded under the intercrop. This could be attributed the additional nutrients fixed by the companion crop. This finding rhymes with Arslan *et al*. (2015) who noted that legume intercropping increases maize yields even under critical weather stress. The intercrop also had the highest number of cobs per plot compared to monocrop. This must have happened due to optimum utilization of moisture, nutrients and solar radiation. The intercropping system led to an increase in canopy cover leading to a drop in evaporation from the soil surface (Karuma *et al*., 2016).

## Conclusion

Planting maize variety Longe 10 H intercropped with beans, under a reduced tillage system, and supplied 60 kg ha$^{-1}$ N fertilizer a season emerged as a promising practice to recommend for improving maize growth and yields.

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