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Research Article

Climate Smart Crop: Evaluation of Selected Mutant Cowpea Genotypes for Yield, Earliness and Ground Cover in Eastern Zambia

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Abstract

The use of climate smart crops in Zambia is an urgent concern by the government and the private sector, as the weather trends show an increasing low rainfall quantity and length of season, with increased temperatures across the seasons. The use of mutation breeding to create variation among cowpea genotypes for climate smart traits (improved yields, resistance to abiotic and biotic stresses) has resulted in promising lines with potential for use in climate change adaptation, especially among farmers. However, there is limited available information on the performance of the mutants. Evaluation of the mutation derived materials is essential in generating information that will be useful in development of appropriate adaptable varieties with good crop performance. Six genotypes were evaluated in a randomized complete block design (RCBD) for traits; grain yield, days to maturity, biomass, ground cover and resistance to aphids in two seasons. The traits were measured as they are known to contribute highly to grain yield and are correlated to climate change adaptation. The weather data in two seasons were collected from meteorological department of Zambia. LT 4-2-4-1 and LT11-3-3-12 mutants showed increased grain yield, earliness and ground cover, compared to their parental variety, Lutembwe, and a recently released variety Lukusuzi, both used as controls. LT 4-2-4-1 recorded the highest yield of 1506 kg/ha while the parent had 1100kg/ha. The number of days to maturity was least (80) in LT 4-2-4-1 and ground cover was at 4.33 compared to 2.33 for Lutembweparental variety. Varying weather conditions, require the use of more early maturing varieties, therefore, genotypes such as LT 4-2-4-1 should be considered by Seed Control and Certification Institute (SCCI) for pre-release. Additionally, LT 4-2-4-1 and LT11-3-3-12 could be useful as breeding lines for ground cover and earliness in other breeding programs.

Keywords: climate change adaptation; *Vigna unguiculata*; weather; breeding lines; performance

Introduction

Cowpea (*Vigna unguiculata L. Walp*) is an annual legume, also commonly referred to as black-eyed pea. The crop is of major importance to the livelihoods of millions of people in less developed countries especially of the drier tropics(da Silva et al., 2019). In Zambia, it provides the bulk of the highly nutritious inexpensive dietary protein intake and valuable micronutrients in the poorer households. The crop makes valuable contribution to agro-ecological systems, especially that most of the recently released varieties in the country, are dual purpose, providing grain for human food and improved fodder for livestock production - making the crop very attractive where land is becoming scarce (Mwila et al., 2022). Cowpea is a drought tolerant and a warm weather crop, well adapted to the Southern and Western regions of Zambia, with poor soils of more than 85% sand, less than 0.2% organic matter, and low levels of

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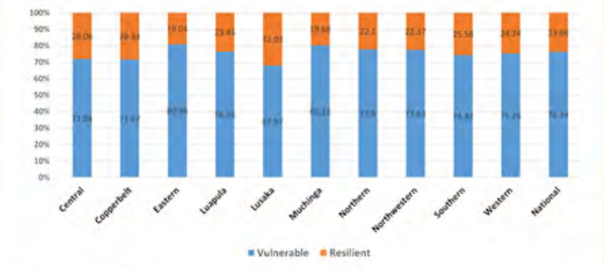
phosphorus (Mwila et al., 2022). Its quick growth and rapid ground cover checkssoil erosion in these areas. The crop has high biomass linked to the ground cover and vigorous growth pattern(Wang et al., 2006). Root, leaf and stalk decay of the crop in situ of the below and above ground biomass, produces nitrogen-rich residues that improve soil fertility and structure (Rusinamhodzi, 2006).

Impacts of climate change

Zambia has been experiencing adverse impacts of climate change. A 30-year study on rainfall from 1970/71 to 1998/99 in Zambia showed a trend towards lower rainfall in Agro-ecological Regions (AER) II and I. A similar study over a longer period of 43 years based on records from 1960 to 2003 revealed evidence to show that Zambia's average annual temperature had increased by 1.3°C since 1960, an average rate of 0.29°C per decade (Mubanga, 2012). The rate of increase was most rapid in the winter, at 0.34°C per decade. The expected increase in temperature, reduction in precipitation and associated extreme weather events such as higher heat-waves, elevated evapotranspiration rates, droughts and floods will not only affect growing season but also seriously threaten national food security, water and energy security as well as livelihoods of communities (Libanda, 2020).

The performance of rainfall in the 2021/22 agricultural season was below normal to normal rainfall, with most parts of the country recording floods and droughts, with all parts of the country reporting a short season from late December/early January to late March, 2022 (Brigadier et al., 2015). The continued correlation between crop performance (yields) and the amount of rainfall received, speaks to the vulnerability of the sector to climate variability. Considering that rainfall is projected to reduce by 0.87 percentage points by 2050 and maize yields have the highest losses (Mulungu et al., 2021a) regardless of whether there are ideal policy conditions and actions, investment into irrigation development and breeding crops that are able to withstand these shocks is critical to making the sector more resilient to climate variations. Econometric estimations done by (Mulungu et al. (2021b) suggests that climatic shocks have a negative and significant effect on resilience, with far reaching effects on food availability. Considering that 76 percent of rural households in Zambia are categorised as vulnerable, this evidence is a source of concern (Figure 1) (Ngoma et al., 2021).



Source: Ngoma et al. 2021

These findings speak to the fact that smallholder farmers are experiencing climate change in the form of reduced and more varied rainfall, and increased temperature, both of which have an impact on crop and livestock production. This is corroborated by the severity designation of the hunger levels in Zambia as serious, the same level as that in 2020, and an improvement from alarming in 2019 (Mofya-Mukuka, 2021). The progress is very slow, considering that climate shocks will progressively increase with time in Zambia. This reality continues to show the need to invest in the key drivers of agricultural development that enhance pro-poor growth and resilience. Specifically, climate smart agriculture, and production of diverse crops, and agro-ecologically appropriate value chain development remain key to reducing vulnerability to climate shocks and enhancing rural livelihoods and food security.

What role can cowpea play?

Legume seed development and release has lagged behind, despite legumes playing a critical role in improving soil fertility, providing nutritious food and are low carbon emitters, which is critical for mitigation of climate change effects. Cowpea seed development has been low in Zambia, with only seven released varieties from 1984 (Mwila et al., 2022). Among them two varieties Lukusuzi and Lunkwankwa, were released in 2018 with improved tolerance to Aluminium toxicity and drought tolerance. There is need to evaluate more varieties for potential in water use efficiency, biomass, soil carbon build up, resistance to insect pests and diseases, with nutritional components as malnutrition also results from climate change effects due to low productivity. The study presents some preliminary findings on key traits of cowpea from screening evaluations. More genotypes are being evaluated for various traits (yields, resistance to bruchid, aphid, *Ascochyta, cercospora*, phosphorous, aluminum and water use efficiency, biological nitrogen fixation, micro and macro nutrient content) that could be useful in cowpea production and use. Therefore, this study set out to evaluate cowpea pre-release genotypes for agronomic performance and the suitability in Agro Ecological Region I.

Materials and Methods

Location of study

This study was conducted in an open field located at Luamba Agriculture Camp in Nyimba district, Eastern province of Zambia. The area is at latitude of 14.56 south, longitude 30.81 east and altitude of 717m. The study was conducted in the valley part of Luamba agricultural camp in Vizimumba block of Nyimba district which is in agro ecological region Iof Zambia, which receives less than 800 mm of rainfall. The area was important for the study because of frequent drought occurences in that location. The experiment was conducted at a farmer's field, in Dyeele village of Chief Ndake's area in Nyimba district of Eastern Province, Zambia.

Research Design

Experimental design used was Randomised Complete Block Design (RCBD) with each genotype being used as a treatment on its own and three replications.

Genotypes used for the study

Six genotypes were used; consisting of varieties Bubebe (BB PRT) and Lutembwe (LT PRT) as parental lines, and a released variety Lukusuzi. The lines used were BB14-16-2-2, LT PRT, LT4-2-4-1 and LT11-3-3-12.

Population of the study

Each plot had 4 lines with the row length of 5 meters. The total area for each experimental unit was 5 meters length with a width of 2.4 meters. Inter row spacing was 0.6 meters and intra row spacing was 0.1 meters, resulting in 200 plants per experimental unit.

Sample population

The sample population of the study was based on 20 plants from the net plot. 10 plants were randomly selected from the net plot for data collection. Sampling procedure was done by selecting the number of plants from the two middle rows and tagging the selected plants for easy identification during data collection.

Data collection

First and second planting were done in December, 2020 and 2021 respectively, after which data was collected from planting until physiological maturity, plant height, biomass, pods per plant, pod length, days to maturity, days to flowering, leaf colour, number of locules, ground cover, plant vigour seeds per pod, aphid and bruchid infestation, plant density, 100 grain weight and yield per hectare. The paper presents and discusses part of the measured parameters, which are earliness, ground cover, biomass and crop yield.

Between 10 and 11 weeks after planting, cowpea plants were rated for general vigor on a scale of 1 to 5 where 1 = lowest vigor and 5 = highest vigor. Ten to 11 weeks after planting was chosen as the interval to take rating and growth measurement data, because at this point, the canopies of the cover crop genotypes were well developed but they were not senescent. Canopy heights and widths were measured. Width was estimated by doubling the distance from the center of the outer row to the canopy edge. Prostrate vine growth that extended beyond the upright portion of the canopy was not considered in the width measurement. Vigor ratings, canopy height and width measurements were used to represent ground cover as described. Earliness was recorded as days to flowering, which was the number of days taken from emergence to when 50% of the plants had flowered in a plot. Yield was measured using the grain weight from each plot and converted to per hectare (Fery & Smith, 2006).

Results

Weather data was collected from the Zambia meteorological department for the area where this study was undertaken for the two growing seasons. Figure 2 shows the rainfall and temperature variations experienced in the area of study.

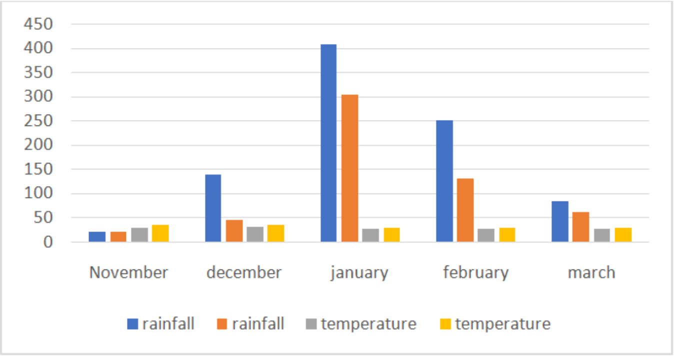


Figure 2: rainfall and temperature patterns in Nyimbain the 2020/21 and 2021/22 rain season.

The graph illustrates the fluctuations of rainfall and temperature readings between the two years. The growing year 2021/22 had lower rainfall and showed increased temperature compared to the previous year, 2020/21. There was very low rainfall activity in the 2021/22 season with November and December having the least rainfall amounts of 20 and 45mm respectively. The highest temperature reading was in December, 2021/22. There was no significant variation between the two years despite the differences observed as such means for the two years were combined in the presentation of the findings.

An analysis of variance (ANOVA) of measured parameters showed that hundred grain weight, aphids, biomass, days to flowering, days to maturity, cowpea mosaic virus, ground cover, leaf colour and number of pod per plant were highly significant (p <.001).

The following parameters e.g. number of locules per pod had p value of 0.033, pod length had probability value of 0.02, number of plants at harvest had probability value of 0.086, plant vigour had probability value of 0.002 and seed per pod had probability value of 0.005.

The summary of analysis of variance is given in Table 1.

Source of variation	*D.F*	*Grain yield*	*Aphid count*	*Number of pods*	*Days to Maturity*	*Ground cover*	*100 grain weight*	*Biomass*	*Locule*	*Pod length*
Genotype	5	4.120***	3.565*	145.991***	81.209*	4.122***	8.865	1.659*	4.016	8.793
Year	2	0.028*	0.061**	9.438	8.902	0.187*	0.137*	0.045*	0.965	0.068*
residual	9	0.429	0.153	3.914	1.879	0.202	0.249	0.027	0.992	3.529
TOTAL	13	27.611	22.205	770.500	548.500	24.000	97.229	8.762	40.278	21.005

D.F: degree of freedom, ***: P<0.001, **:P<0.05, *:P<0.01

Table 1: Analyses of Variance for the means of the measured parameters.

Grain Yield

There were significant variations in terms of grain yield of different cowpea genotypes with the probability value of <.001. The highest grain yield for both years of 1612 kg/ha and 1.567 kg/ ha respectively were obtained by LT 4-2-4-1 a Lutembwe derived line followed by Lukusuzi with 1.464 kg /ha. Lukusuzi is a lutembwe derived released variety. LT 11-3-3-12 obtained 1.192 kg /ha, BB 14-16-2-2 gave out a grain yield of 1.167 kg/ha with Lutembwe parent having 1.108 kg/ha. The least was Bubebe parent with the grain yield of 0.706 kg/ha.

The two mutants LT4-2-4-1 and Lukusuzi had the higher magnitude of 37% over the parent genotype Lutembwe and BB14-16-2-2 cowpea genotype had a magnitude of 65% over the parent Bubebe.

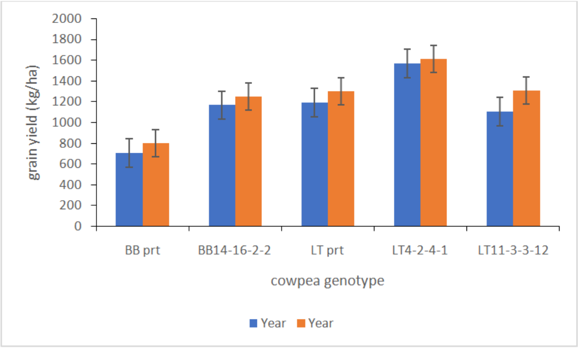


Figure 3: Variation of grain yield among cowpea genotypes.

Days to Maturity

The number of days to maturity showed significant (P<0.01) differences among the genotypes. The least number of days to maturity was 84 days for LT 4-2-4-1. LT11-3-3-12 also recorded low number of days (91.67) compared their parental genetic source variety LT prt (Lutembwe) at 96.67 days to maturity. A newly released variety, Lukusuzi, was found to have low number of days to maturity (86.67). The highest number of days to maturity were recorded by BB prt (99) with its' progeny, BB14-16-2-2. LT 4-2-4-1 had less than eighty-five days to reach physiological maturity while the parent material, Lutembwe had over hundred days. The mutant lines matured earlier than their parents. There were no significant variations among the genotypes between the two years.

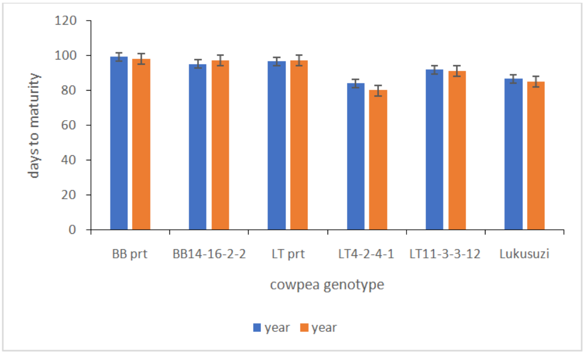


Figure 4: Variation of cowpea genotype for days to maturity.

Ground Cover

There were highly significant variations amongst the genotypes in terms of the ground covered by the plants and also the plant vigour (p<.001). The genotype with the highest ground cover was obtained by Lukusuzi, LT4-2-4-1 and LT 11-3-3-12 compared to the parent Lutembwe. BB 14-16-2-2 had higher ground cover than the parent Bubebe. Lukusuzi, LT4-2-4-1 and LT11-3-3-12 had a magnitude of 86.9% higher than the parent while BB14-16-2-2 had a magnitude of 130% more than the parent. Plant vigor responded in a similar way across the genotypes ground cover presentation.

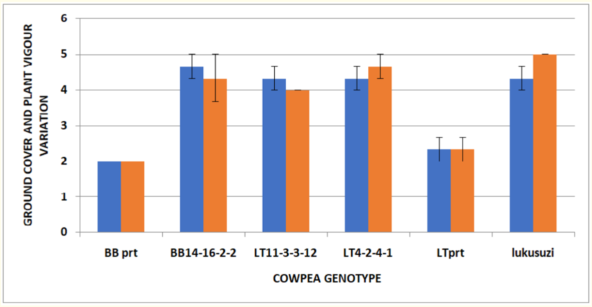


Figure 5: Variation of ground cover and plant vigour on cowpea genotype.

Discussion

The analyses of variance showed that there are significant (P<0.001) differences among the genotypes of the measured traits. Among the traits with high variability in the different genotypes were grain yield, days to maturity and ground cover.

Genotype BB 14-14-2-2 had a higher yield of 1,167 kg/ha compared to the 706kg/ha of the parental genotype BB PRT. Similarly, LT 4-2-4-1 compared to LT PRT. This showed the genetic potential of mutation bred materials (Raina et al., 2020). The mutants had more number of pods per plant compared to their parents as such resulted in the presentation of higher grain yields. Bubebe and Lutembwe parents had the lowest number of pods per plant. Induced mutation breeding could have potentially caused the change in the genetic makeup of the parental materials in the expression of the grain yield resulting in higher yields of the progeny compared to the parental genotypes (Horn et al., 2016). In several mutation-derived varieties, the changed traits have resulted in synergistic effect on increasing the yield and quality of the crop, improving agronomic inputs, crop rotation, and consumer acceptance (Zimmerman et al., 2016). This also suggests hybrid vigor in the progeny where the hybrids had significant desired heterosis over the better parent for various traits. The significant difference due to parent. Hybrid x environment for days to maturity, branches per plant and protein content indicated instability of hybrids. The lower magnitude of mean squares due to year (denoting environment) than the genotype indicated greater genotypic influence over yield and less effect of environmental fluctuations of the years on the hybrids. Lines BB14-14-2-2 and LT 4-2-4-1 could be useful as parental material in breeding for increased yields in cowpea. Yields greater that 1ton/ha show potential as the yields at farmer level currently in the country average around 0.8tons/ha.

Earliness in crop maturity is an essential crop characteristic especially when considering climate change adaptation. The response of the genotypes of cowpea for the number of days to maturity showed genetic variation among the genotypes. LT 4-2-4-1 had the least number of days to maturity, at 80 days in the 2021/22 season, after planting compared the highest of 99 days for BBprt and its parental genotype LTprt at 97 days to maturity. Early maturity reduces plant stress during drought occurrences and delayed seasonal start of the rainy season (Shavrukov et al., 2017). In Ghana, as a response to the long dry spells, short duration improved cowpea varieties have been developed and promoted among smallholder farmers who are largely the most affected (Martey et al., 2022). In Zambia, especially the southern and eastern parts of the country, the 2021/22 rain season lasted for only 3 months compared to the known 6 month rain period, with floods and droughts experienced countrywide (Giews-Fao, 2022). Going by this, cowpea materials that mature within three months, in this case, LT 4-2-4-1, would be recommended into these areas. Other genotype traits such as grain yield, biomass and their stability have to be considered as recommendations are being made, to ensure climate smartness.

The crop biomass of the cowpea lines varied among the genotypes and this was linked to different crop and leaf architecture increasing ground cover among some of the genotypes. The mutant genotypes, BB 14-16-2-2 and LT 4-2-4-1 had high ground cover scores as well as relatively high plant vigour. The leaf shape and crop architecture are vital characteristics in increasing adaptiveness of a crop to especially drought and affecting ground cover (Basu et al., 2016), by its ability to conserve moisture. The leaves for the LT 11-3-3-12 and the LT 4-2-4-1 are ovate, which made them cover more ground area, but also showed indeterminate nature, this allowing them to cover ground for a longer period of time.

The vigorous vine growth exhibited by some genotypes also appeared to contribute to their ability to grow vegetatively, increasing the height and width quickly thus being able to cover a considerable area of land. The ground cover helps the cowpea materials to withstand drought occurrences as they can maintain moisture (Thierfelder et al., 2018).

Conclusions

Cowpea is definitely a climate smart food now and for the future, with a high contribution to food and nutritional security, especially as it demonstrates the ability to have increased yields, earliness in maturity and increased ground cover for a long period of time. These characteristics are important components of climate change adaptation, especially that these varieties have demonstrated increased water use efficiency (Munyinda, 2020). The mutant derived materials perform better than their parental genotypes and are recommended for consideration as prelease genotypes. Genotypes, BB 14-16-2-2 and LT 4-2-4-1 are varieties that showed consistent high yields over the two years, with great potential to perform even better under the right conditions.

Additionally, as the number of days to maturity is becoming an increasingly important attribute to farmers in Zambia, with the shorter periods of rainfall as well as low amounts of rainfall and high temperatures, varieties that mature early are required. LT 4-2-4-1 had the least number of days to maturity. This genotype shows promise for use as an early and high yielding variety, with relatively high ground cover and plant vigor, in an area with relatively poor weather conditions. The possession of these characteristics increase the chance of cowpea to be considered as a climate smart crop in Zambia, by the government and other development and private organisations, which would contribute greatly to improving farming systems of farmers. Furthermore, contribute to the national food and nutritional improvement, as a source of food. The vigorous growth of the crop, allows sufficient ground cover and increases the chance of leaves to be used as a food and have more biomass for livestock. It is recommended the genotypes be evaluated in the next seasons in different agro-ecological areas for a stability check for the traits measured in this trial and others and eventual pre-release consideration.

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