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Growth and yield responses of new short season maize varieties (*Zea mays* L.) grown in Zimbabwe low rainfall areas under hand hoe basin technique

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Abstract

Maize is the staple food, but persistently low yields of the crop in Manyau village, Nyanga District, due to farmers' failure to choose the most potentially productive variety triggered off investigations of the growth and yield of new short season varieties introduced in the area. A field trial was carried out under hand hoe basin technique (HHBT). Treatments were Seed Co. (SC) 301, SC303, SC403 and SC419 cultivars; replicated 4 times. SC403 was the standard. A randomized complete block design (RCBD) was used. Varietal treatment showed highly significant ($P<0.001$) effect on plant height, leaf length (at 2, 4, 8 and 14 weeks from seed emergence), dry grain weight per plant and total dry grain yield per plot under HHBT. Plant height and leaf length of all cultivars increased with increase in weeks. There were significant differences in growth between SC419 and the standard, but significant ($P<0.05$) differences with the 3 series were prominent. The heaviest dry grain weight was recorded from SC419 (334.2 g/plant) and the least was recorded from SC301 (154.8 g/plant). The highest dry grain yield was from SC419 (21.33 kg/plot), whereas the least was from SC301 (11.80 kg/plot). The percentage difference was 44.6%. SC419, at 14 weeks, recorded highest of the cultivars in all parameters. SC403 recorded second highest. Most varieties show highest growth and yield potential under HHBT, irrespective of the series they belong to. In conclusion, farmers in semi-arid regions may grow SC419 as the first option, and SC403, as a second option, under HHBT.

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Introduction

Maize is one of the world's three most important cereals along with wheat and rice. Maize is also the staple food for most households (Mvumi *et al.*, 2013) in Africa South of the Sahara.

The crop is an important livestock feed both as silage and as crop residue; the grain is used industrially for starch and oil extraction. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. The decline in soil fertility at household level and the community at large, apparently caused by conventional tillage and poor choice of varieties adapted to the area and tillage system best suited to the area, are the most important barriers to food security (Botiono *et al.*, 2006). Other factors include low input use (Bruce *et al.*, 1995; Holland, 2004; Botiono *et al.*, 2006).

Holand (2004) reported that soil degradation, caused by continual soil inversion due to conventional tillage which uses animal-drawn mouldboard plough or tractor drawn disc plough, results in low crop yields. Conventional tillage is described as a farming technique which uses intensive primary and secondary tillage implements (Elwell, 2013). Conventional tillage can lead to low levels of soil organic matter and to degradation of soil structure which can result in compacted and hardsetting soil (Chivenge *et al.*, 2007).

Globally, conservation farming has been promoted as a means to protect soils from erosion and compaction. Conservation farming comprises the simultaneous application of three agronomic principles: (1) minimal mechanical soil disturbance (2) maintenance of permanent soil covers with organic mulch and (3) diversification into legume-based crop rotations (Twomlow *et al.*, 2008). One of the best CF techniques is hand hoe basin technique (HHBT) (Protracted Relief Programme, 2005; Mazvimavi and Twomlow, 2009; Nyamangara and Matizha, 2010). When making HHBs, a pit, which is dug and formed into a basin-like structure in which manure and inorganic fertilisers are precisely applied (Zimbabwe Conservation Agriculture Taskforce-ZCATF, 2009); Mashingaidze *et al.*, 2012; Nyamangara *et al.*, 2014). Mulch is also applied in the basin. Seed is sown in the basin where it will cherish the nutritive materials applied in it. Hand hoe planting basins have been reported in literature to increase low-yielding cultivars adapted to semi-arid regions (Mashingaidze *et al.*, 2012; Manyangara *et al.*, 2014). When the basins are prepared, the rest of the other space is left untilled (Nyamangara and Matizha, 2010). Hand hoe planting basin technique has been adopted by a large number of farmers in Sub-Saharan Africa (Mazvimavi and Twomlow, 2009). However, varieties from different seed houses differ in their adaptability in specific locations. New varieties need research to find their adaptability index, which is a determinant factor for their yielding potential.

Most maize communal farmers (more than 75%), including Manyau farmers, grow maize SC403 under conventional tillage (Agritex, 2012). The yields realised have, however, been always below the minimum expected from the cultivar in Manyau and other parts of Nyanga, considering that the crop is well adapted to the environmental and climatic conditions of the area (Agritex, 2012).

There has not been any study to determine the performance of the new varieties of seed houses which are now on market and already grown in the district, for example SC301, under HHBT. Hand hoe basin technique is advocated as one of the most suitable techniques in the arid areas (ZCATF, 2009).

If trials could be done, they would show many farmers how the growth and yields of the new varieties differ. This would then enable the farmers to choose the best adaptable and yielding variety in their area.

The current study seeks to investigate the most adaptable variety in terms of growth and yield, when grown under HHBT, among the newly introduced varieties of SC in Manyau, Nyanga District.

Methods and materials

Study area

The study was done in Manyau village located in Nyamaropa, ward 13, Nyanga District. The location is situated some 50 km North East of Nyanga town in Manicaland province. It falls under natural region 3 which receives an average rainfall of 500 mm per annum and usually experiences severe dry spells during. The rainy season in the area is relatively short. The average temperatures are 14 °C in winter and 32 °C in summer. Manyau village is characterised by mainly sandy soil (Agritex, 2012).

Treatments and experimental design

The maize cultivars, which were the treatments used in the current study, were SC301, SC303, SC403 and SC419.

The treatments were replicated four times. SC 403 was used as the standard because it is the main short season variety which has been grown by nearly every farmer in Manyau village, Nyanga, but its growth and yield potentials have not been investigated through research in combination with the newly introduced varieties in the area.

The size of each plot was 5 by 5 m with a total of 40 basins per plot. The treatments were arranged in a randomised complete block design (RCBD). The experiment was repeated twice.

Land preparation

Manual technique was employed to organize and prepare the land for planting. No sophisticated agricultural implements were used to clear and prepare the land. A hoe was used to clear the land for the experiment. Hand hoe basin was used for the planting. Hand hoe basin can be defined as a planting system that at least 30% of the soil surface is covered by crop residues (ZCATF 2009). The basins were covered with mulch from the previous maize crop and the hoe was only used to open up the planting basins.

The prepared hand hoe basins were 15 cm long x 15 cm wide, and 15 cm deep, spaced at 90 cm × 60 cm (Protracted Relief Programme, 2005; Twomlow *et al.*, 2008).

Planting

The maize for the current experiment was grown under rain fed conditions. An amount of 5 g compound D, was applied per each planting basin and mixed with 500 g of local goat manure, which was well decomposed. Sowing was done immediately after the first effective rains, which were received on 19 November in 2016/2017 growing season, and on 26 November in 2017/2018 growing season. Farmers in the area normally plant in December.

The plot area was 400 m^2. Each cultivar was planted on an area of 100 m^2. Planting depth was 4 cm. Three seeds were sown in each basin at different positions and then thinned out 7 days after emergence by removing the weakest seedlings, leaving one strongest seedlings per basin (Mutungwe and Mvumi, 2017). This was done to manage plant density, since high plant density adversely affects plant growth and yield.

Topdressing

Ammonium nitrate (34.5% N) fertilizer was applied as split dressings at 4 and 9 weeks post emergence, at 4.5 g per basin; 2.5 g were applied at 4 weeks post emergence and the remaining 2 g were applied at flowering stage. Ammonium nitrate application rate was 90 kg/ha (Mutungwe and Mvumi, 2017).

Weed control

Hoe weeding was done to control weeds which included wandering due (*Tradescantia* spp), black jack (*Bidens pilosa*) and pig weed (*Amaranthus hibridus*) which were found especially in the basins where moisture and nutrients promoted weed-seed germination and growth.

Growth measurements

Sampled plants in each plot were tagged. Measurements (in cm) were taken at week 2, 4, 8 and 14 from seed emergence. Measurements of plant samples for each plot (cultivar) were added and averaged.

Yield measurements

Dry grain weight and total yields were recorded after harvesting maize at maturity. The grain was taken from counted tagged plants of SC301, SC301, SC403 and SC419 plots. Further drying was done until the tester used to test moisture content showed 12.5%. The grain was weighed and averaged to get dry grain weight per plant of each cultivar. Total yields were obtained per plot by adding up all the yields of each cultivar and averaged. Yields were converting to kg.

Data analysis

Analysis of variance (ANOVA was done using GENSTAT 14th Edition version. Means were compared and separated using Tukey's HSD test (P<0.05).

Results

Plant height

There was significant (P<0.001) increase in plant height by all cultivars (Table 1). In week 2, the mean height of each cultivar was significantly (P<0.05) different from each other. Also, the means of the height for SC 301 and SC 303 showed no significant (P >0.05) difference in week 4, 8 and 14.

Table 1. Effect of varietal treatment under HHBT on plant height at specified periods (weeks).

Plant height (cm)				
			Weeks	
Treatment	2	4	8	14
SC 301	9.98^{a}	35.27^{a}	83.92^{a}	158.1^{a}
SC 303	10.55^{b}	35.95^{a}	85.27^{a}	160.2^{a}
SC 403	11.58^{c}	38.25^{b}	94.95^{b}	178.3^{b}
SC 419	13.58^{d}	42.00^{c}	98.90^{b}	187.0^{c}
P value	<.001	<.001	<.001	<.001
$LSD_{(0.05)}$	0.4063	1.462	3.127	4.598
CV%	1.3	1.6	1.9	1.9

Means within a column followed by different superscript letters indicate a significant difference using Tukey's HSD test (*P*< 0.05). Standard (control) = SC 403.

The mean plant height of each cultivar was observed to have a faster increase in the period after 4 weeks. At week 14, the plant height of SC 419 was significantly (P<0.05) different from the standard (SC403). The mean height of SC419 was 187 cm, while SC 403 (the standard) had 178.3 cm. The percentage difference was 4.6%. The difference between SC 419 and the least cultivar (SC 301) was 15.5%. Heights of all cultivars were greatest at week 14 (Table1). However, SC419 had the greatest mean plant height.

Leaf length

There was significant (P <0.001) increase in leaf length of all the cultivars. The mean leaf length of each cultivar was observed to have a faster increase in the period after 4 weeks. At week 8, mean leaf lengths of the maize plants were significantly different from each other. SC419 produced the greatest leaf length while SC301 produced the least.

There was no significant (P>0.05) difference in leaf length between SC301 and SC303 at 2, 4 and 14 weeks after emergence. At week 14, the leaf length of SC419 was significantly (P <0.05) different from that of the standard SC403, with SC 419 having longer leaves (129.1cm) than of SC 403 (119.7cm) (Table 2).

Grain weight per plant

Varietal treatment showed highly significant (P <0.001) effect on dry grain weight per plant. According to Table 3, the heaviest average dry grain per plant was recorded from SC419 (334.2 g) and the least was recorded from SC301 (154.8 g). The percentage difference was 53.6%. The dry grain weight for SC 419 (334.2 g) was significantly different (P< 0.05) from the standard (SC403) (210.0 g). The difference here was 37%.

Table 2. Effect of varietal treatment under HHBT on leaf length at specified periods (weeks).

Leaf length (cm)				
	weeks			
Treatment	2	4	8	14
SC 301	10.22 [a]	35.55 [a]	66.53 [a]	87.5[a]
SC 303	10.37 [a]	36.38 [a]	73.15 [b]	89.7 [a]
SC 403	11.22 [b]	38.55 [b]	92.38 [c]	119.7 [b]
SC419	13.25 [c]	41.70 [c]	99.38 [d]	129.1 [c]
P	<.001	<.001	<.001	<.001
$LSD_{(0.05)}$	0.2504	1.103	2.641	1.627
CV%	1.9	2.7	3.3	0.8

Means within a column followed by different superscript letters indicate a significant difference using Tukey's HSD test (*P*< 0.05). Standard (control) = SC 403.

Total dry Grain Yields per plot

According to the analysis of variance (ANOVA) test, varietal treatment significantly (P<0.001) increased total yield per plot.

The highest dry grain yield was from SC419 (21.33 kg/plot), whereas the least dry grain yield was obtained from SC301 (11.80 kg/plot) (Table 3).

The percentage difference was 44.6%, while the percentage difference in total dry grain yield between SC419 and the standard (SC403) was 16.7%.

Discussion

Growth

According to Table 1, the study showed that SC419 produced the highest plant height of 187.0 cm as compared to all the other maize varieties used in the research. This was because SC419 is the latest variety with improved traits of the 4 series category. Agritex (2012) reports that the 4 series (SC419) cannot perform less than the 3 three series (like SC303) under normal environmental conditions. On the other hand, SC301 produced the least plant height (158 cm). SC419 cultivar had the fastest growth rate.

Table 3. Effect of varietal treatment under HHBT on dry grain and total dry grain weights at harvest.

Treatment	Dry grain weight	Total dry grain yield
(variety)	g/plant	kg/plot
SC 301	154.8 [a]	11.80[a]
SC 303	161.2 [a]	12.83 [a]
SC 403	210.0 [b]	17.76 [b]
SC 419	334.2 [c]	21.33 [c]
P value	<.001	<.001
$LSD_{(0.05)}$	21.53	0.756
CV%	2.6	1

Means within a column followed by different superscript letters indicated a significant difference using Tukey's HSD test (P< 0.05). Standard (control) = SC 403.

This is in agreement with the study of (Rocksrom *et al.*, 2009) who reported that some maize cultivars can be more adaptable; are more drought tolerant; use nutrients more efficiently; grow taller than most short season cultivars in dry areas. Growth of the four cultivars was almost the same in the first 2 weeks. From week 4 to week 14, SC419 had faster growth rate than the other cultivars; the greater height contributed to increased potential of capturing more sunlight for photosynthesis than the shorter cultivars (SC301, SC303 and SC403). Generally, maize grows faster from 4 weeks to 7 or 8 weeks than from 2 to 4 weeks (Bell, 2017). Hand hoe basins had soil nutrients like manure and ammonium nitrate, which had been applied. According to literature, ammonium nitrate increases the growth rate of more adaptable cultivars in arable areas (Sawi, 1993).

The highest leaf length was recorded from SC419 which was 129.1 cm and the least was 87.5 cm on SC301. SC419 had higher leaf length than the standard (SC 403). According to literature, plant height and leaf length have proportional growth (Vanlalhluna and Sahoo, 2011; Bell, 2017).

Yield

Varietal treatment under HHBT promoted maize yield. This research indicated that SC419 produce the highest dry grain yield of all the other tested cultivars. This may be a result of mulch and nutrients applied in the basins. Mulch conserves moisture through prevention of evaporation and reduces loss of water through soil erosion. Enough soil water promotes photosynthesis which is necessary for plant growth, and coupled with nutrient availability, seed formation or growth is enhanced (Twomlow *et al.*, 2006). Indeed, varietal yield response under HHBT can thus be affected by soil type, amount of rainfall, management practices (which include inorganic fertilizers and organic type and rates), mulching and prevailing temperature (Nyamangara *et al.*, 2013) and varietal differences.

Smallholder farmers in Zimbabwe have been found to plant up to three weeks earlier (early planting) when using HHBT than planting under conventional tillage (Mashingaidze *et al.*, 2012). This is a condition that normally favours good establishment of the main cereal crops because when using hand hoe basins system, farmers do not have to wait for the first rains to soften the soil before they can plough (Mazvimavi and Twomlow, 2009). Farmers who plant early tend to achieve higher yields in Zimbabwe due to the materials contained in the basin. (Twomlow *et al.*, 2009). Besides, the crop is most likely to gain the number of heat units it requires for growth and the ultimate yield (Liu *et al.*, 2010). Despite being grown in hand hoe basins which had inorganic and organic fertilizers, mulch and conserved moisture, the SC301 and SC 303 cultivars could not produce heavier dry grain. Their genetic make-up caused them to respond less positively. This counts negatively on adaptability.

Conclusion

The study investigated the growth and yield of four SC short season cultivars under HHBT to determine the most adaptable and, hence, productive cultivar, in terms of growth and yield, in Manyau. The cultivar treatments used had highly significant ($P<0.001$) effect on all parameters measured. Plant height and leaf length of all cultivars increased with increase in weeks. The mean height of SC419 was 187 cm, while SC 403 (the standard) had 178.3 cm; the leaf length of the 4 series (SC419) was 129.1 cm, while the least (SC301 was 87.5 cm. The cultivars also significantly ($P<0.001$) increased dry grain weight and total dry grain yield. Growth and yield of SC419 were found greatest of all the other cultivars (SC301, SC303 and SC403), followed by SC403, at all the weeks, when the measurements were taken.

The means for dry grain weight and total grain yield, SC419 and SC403 were significantly ($P<0.05$) different from each other, while the 3 series had no significant ($P>0.05$) difference in each case. The heaviest dry grain weight was recorded from SC419 (334.2 g/plant) and the least on SC301 (154.8 g/plant). The highest dry grain yield was from SC419 (21.33 kg/plot), whereas the least dry grain yield from SC301 was 11.80 kg/plot. The study has shown that SC419 performs best, compared to SC301, SC303 and even to SC403, when grown under HHBT. From the results of the current study, it is recommended that farmers in semi-arid areas which have infertile soils may grow SC419 under HHBT, where it proved to be most adaptable, (or SC403 as a second option) as it outperformed the 3 series and the SC403 in terms of growth and yield.

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