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Comparison of growth and yield adaptability indicators of two maize (*Zea mays* L.) cultivars under planting basin technique in Zimbabwe

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In eastern semi-arid Zimbabwe, planting basins are mostly used to boost maize yields, but still low yields are often obtained due to poor choices of varieties to grow. A comparative study of growth and yield of the only two locally and commonly grown Pioneer cultivars (P2859W and PHB3253) under planting basin technique (PBT) was carried out to determine a more adaptable cultivar in Guhune, eastern Zimbabwe (NR IV). The study was done in 2012/2013 and 2013/2014 growing seasons. An experiment was laid out in a Randomized Complete Block Design (RCBD), with the two cultivars, each replicated four times. Yield, leaf length and plant height were measured and averaged. Results showed that PHB3253 had growth of 75.2 cm after measuring at 2 weeks interval for 10 weeks. Its growth was significantly ($p<0.05$) higher in terms of plant height than P2859W. Leaf length of P2859W was not significantly ($p>0.05$) greater than PHB3253. Grain yield of PHB3253 (35.1 kg) was significantly ($p<0.05$) greater than that of P2859W (26.6 kg). PHB 3253 is therefore more adaptable to semi-arid conditions under basin technique as signified by its higher growth and yield than P2859W. It is therefore recommended that farmers who use planting basins in semi-arid areas for growing short season maize cultivars (P2859W and PHB3253) should opt for PHB3253 for better productivity.

Key words: Early maturing cultivars, PHB3253 and P2859W performance, adaptation.

INTRODUCTION

Maize (*Zea mays* L.) is the most important grain crop in Southern Africa. It is the staple food of 12.5 million inhabitants of Zimbabwe, which is part of Southern Africa. The crop is grown in all natural regions (NR) of Zimbabwe, including dry marginal areas of NRs IV and V that receive between 450 to 650 mm rainfalls annually (Chitagu et al., 2014). These regions, is dominated by the highest proportion of the smallholder population (Chimhowu et al., 2009; Mehretu and Mutambirwa, 2006), which have the least agricultural potential (Vincent

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Table 1. NR differences according to rainfall and length of growing season in Zimbabwe.

Parameter	Influence of rainfall (mm) per annum on LGP				
	Natural region				
	I	II	III	IV	V
Rainfall	1000	1000-700	700-550	600- 450	500
LGP (days)	165	150-165	135-150	105-135	105

Adapted from Mugandani et al. (2012). LGP, length of growing period.

and Thomas, 1960).

Zimbabwe has five (I to V) major natural regions. The quality of the land resource declines from NR I through NR V (Moyo, 2000; Vincent and Thomas, 1961). Rainfall, temperature and soil type, among other factors, influence the agricultural potentials within the zones (Vincent and Thomas, 1962). For example, in NR IV the soils are poor, temperatures are usually high in summer, and rainfall is low and erratic. Moisture availability (rainfall) and temperature also influence the length of growing period (LGP) (Table 1) (Mugandani et al., 2012).

They, thus affect crop growth and yield. Against this background, manipulation of the biophysical environment influences adaptability of a cultivar. Farming communities in NR IV manipulate the environment by practicing various conservation techniques which include planting basin technique (PBT) to enhance maize growth and yield.

Southern Africa indicates a decline in mean annual rainfall of 40%; the region is also expected to experience a 3.7°C temperature increase in summer and a 4°C increase in winter (Intergovernmental Panel on Climate Change-IPCC, 2007). Zimbabwe is already in serious stress of such semi-arid conditions (Nyabako and Manzungu, 2012). Smallholder farmers, who form the bulk of the farming population in southern Africa, will be worst affected because of a lack of capacity to use the right technologies which are adaptable to such conditions (Nyabako and Manzungu, 2012).

Mean maize yield levels have been reported in declining over the last 20 years under conventional farming where whole fields were ploughed. Mean maize grain yields fluctuate around 1 tha^{-1} in high potential areas such as in natural region II and III, while in NR V, the yields are mostly below 500 kgha^{-1} (Food and Agricultural Organization/World Food Program (FAO/WFP) 2010; Musiyiwa et al., 2014). In a yield comparative study of maize yields in Zimbabwe between conventional tillage (1 t was produced on 5 ha and PBT (1 ton 1.2 ha). PBT produced higher yields per unit area than conventional tillage (Jerie and Mugiya, 2010). Low yields obtained in Southern Africa from conventional tillage are largely due to low soil fertility and moisture content, which have inadequate inputs and increasingly unreliable rainfall patterns [International Maize and Wheat Improvement Center, commonly called by its Spanish acronym CIMMYT for *Centro Internacional de Mejoramiento de Maíz y Trigo*- (CIMMTY, 1992)].

Coping and adaptation options for smallholder farmers in low rainfall areas include crop choices (Kurukulasuriya and Mendelsohn, 2008) and cultivar choice. However, farmers in NR IV usually try to expand cropping areas use to compensate for low yields. Unknowingly, these farmers end up growing crop cultivars that are even not adaptable to their specific farming areas. It is recommended that on selecting cultivars, one has to consider the agro-ecological region and growing season length (Agronomy Research Institute - ARI, 2002).

The aforementioned environmental problems compelled the government, Non-Governmental Organizations, farmers and all other related stakeholders to search for alternative production methods that are based on sound programs for conservation and management of natural resources to boost rainfed maize yields in the rural sector. Reports in literature indicate that in Zimbabwe, farmers in NR IV obtained maize yields of 3 tha^{-1} under tied-ridges as compared to the average of about 1.5 tha^{-1} under conventional tillage treatments (Motsi et al., 2004). Work done by Nyamangara and Matizha (2010) showed that PBT was one of the best alternatives which were found to utilize land and other related resources in dry areas in the most sustainable manner. and Giller (2012) found that PBT is highly needed in southern Africa because it enhances water harvesting and targeted application of fertilizers. PBT in some parts of southern Africa has been adopted by a large number of farmers (Mazvimavi and Twomlow, 2009).

PBT falls under specific components of conservation farming (CF) (Protracted Relief Programme 2005; Mazvimavi and Twomlow, 2009). A pit, which is dug and formed into a basin-like structure, is the planting station where seed is sown. The rest of the other space is left untilled. This pit went through several stages before being refined to a plant basin. The concept was first coined by Oldreive in Zimbabwe (1993). It filtered into Zimbabwe as a modification of the traditional pit system which was started as a variation of the Zai Pit system from West Africa (Twomlow et al., 2008). It was subsequently further modified and promoted in Zambia by the Zambian Farmers Union Conservation Farming Unit (Haggblade and Tembo, 2003). The technology was then received in Zimbabwe after undergoing these stages

Table 2. Classification of maize varieties according to days to maturity.

Variety	Minimum days	Maximum days
Late	145	160
Medium	135	145
Early	115	135

Source: Nyabako and Manzungu (2012).

of modifications.

One of the known advantages of PBT under CF is moisture conservation (Zimbabwe Conservation Task Force-ZCATF, 2009). PBT also enables precision application of both organic and inorganic fertilizers as they are applied directly into the pit and not broadcasted (ZCATF, 2009). In marginal areas, the technique serves as the best solution to low yields of cultivars which could be well adapted in specific locations of semi-arid regions. Zimbabwe has the three main seed houses namely: Seed-co, Pannar and Pioneer. Generally, they supply late, medium and short season varieties which are classified according to days of maturity (Table 2).

Among them, Pioneer has become the commonest supplier of early maturing varieties to communal farmers in dry parts of the country. Early maturing varieties which are mostly short season varieties (SSVs) have improved characteristics which include drought tolerance and heat resilience. Pioneer company gives benefits like seed and fertilizer free to farmers in Chimanimani who grow its cultivars and offers competitions, where winners are given machinery and large amounts of the company's short season varieties. After realizing this, communal farmers in semi-arid parts of Chimanimani, Zimbabwe have resorted to grow, mainly and solely, the Pioneer short season maize cultivars (P2859W and PHB3253). It takes 115 to 135 days respectively to mature (Table 2). Farmers complement these characteristics with planting basins practice so as to, hopefully, obtain sustainable yields.

Planting basins have been reported in literature to increase maize yields in semi-arid regions when manure and fertilizers are added (Mashingaidze et al., 2012; Nyamangara et al., 2014). The two technologies in planting basins and fertilizer application in the basins can, increase yields if the correct choice of well adapted cultivar to a particular environment is done. Most communities do not use planting basins because of several reasons which include; some farmers not being aware of the advantages of planting basins and the labour involved in preparing the basins. Mrs Mboto and some farmers in NR IV and V had not been using planting basins to grow their maize. The current research used growth and grain yield as adaptability indicators of P2859W and PHB3253 cultivars in Guhune, a core semi-arid part of Chimanimani District, Zimbabwe. The cultivars were evaluated under PBT. The study, herewith, determined a more adaptable cultivar between the only two cultivars when grown.

MATERIALS AND METHODS

Study area; NR 1V

Location

The study was carried out in Chimanimani District, in eastern part of Zimbabwe. The country is located between 15°37' S to 22°24' S and from longitudes 25°14' E to 33°04' E; and covers an area of 390 580 km^2 (Mugandani et al., 2012). The coordinates of the town of Chimanimani are: 19°48' 0.00"S, 32°51' 36.00"E (Latitude: 19.8000; Longitude: 32.8600). The research was done in Guhune communal rainfed area, ward 4, at Mrs Jane Mboto`s plot. The plot site is 65 km from Chimanimani.

Rainfall and temperature

The research area, which is in NR IV, is characterized by low range of annual rainfall 450 to 550 mm with less than 14 rain pentads each season, and experiences dry spell during summer. In this NR, rainfall intensity, reliability and distribution are significantly not conducive for maize production (Igbekele, 1975). Temperature ranges from 32 to 40°C in summer while winter temperatures range from 15 to 30°C.

Soil type and conditions

The pH of the soil is 6.0. The soils are sandy soils derived from granite rock and contain 75% sand and less than 20% clay (Nyamapfene, 1991). The study area has reddish coloured soils which fall in Fersiallitic group, under the family 5G which is dominated by coarse grained sandy soils (Thompson and Purves, 1978). The soils are degraded, and hence, have low nutrient status and water holding capacity. They develop low organic and base status and are prone to erosion. The site has a south facing with a slope of ±5% which further increases run-off and soil drainage.

Treatments and experimental design

Performance comparison was carried out between two cultivars (P2859W and PHB3253). The two cultivars were the only commonly grown in early maturing cultivars, advocated by Pioneer in Guhune, under PBT (Agriculture Technical and Extension Services-AGRITEX, 2012). What the community critically needed was a more adaptable cultivar, in their area specially earmark for planting basins. The area experiences low rainfall, and has poor soils. This area was earmarked for maize cropping under planting basins. In such conditions, farming community in Guhune was in dilemma as to which is to be chosen among the two to be grown, after considering the better one in terms of growth rate and yield performance. Therefore, P2859W and PHB3253 were used as treatments in this study (Treatment 1 and Treatment 2 respectively); both were white, early maturing hybrids. Each treatment was replicated 4 times. The 4 plots of each cultivar measured 10 m length x 5 m width. The design was Randomized Complete Block Design (RCBD).

Planting basins and planting procedure

Basins were 15 cm long x 15 cm wide and 15 cm deep, spaced at

Table 3. Growth (plant height) of P2859W and PHB3253 in Guhune dryland in 2012/13 and 2013/ 14 growing seasons.

Treatment	Mean growth (cm) of maize in all plots after emergence					Mean of means for the 10 weeks
	Week 2	Week 4	Week 6	Week 8	Week 10	
P259W	13	30	52	120	150	73
PHB3253	13.5	30.5	55	122	155	75.2

Table 4. Growth (mean leaf length) of P2859W and PHB3253 in 2012/2013 and 2013/2014 growing seasons.

Treatment	Mean leaf length (cm) of maize in all plots					Mean of means for the 10 weeks
	Week 2	Week 4	Week 6	Week 8	Week 10	
P2859W	16	54	67	80	90	61.4
PHB3253	16.5	54.5	67.5	84	95	63.5

90 cm × 60 cm (Protracted Relief Programme, 2005; Twomolw et al., 2008).

In NR 1V, growing season in rainfed conditions starts usually in November and ends in March. Planting starts in the first effective rains. The maize for the current experiment was grown under rainfed conditions. An amount of 5 g compound D, using a cup size of 5, was applied per each planting basin and mixed with 500 g of local cattle manure, which was well decomposed. Planting was done in planting basins on 16 November 2012 to 2013 growing season, on plot area of 200 m^2. Each cultivar was planted on an area of 100 m^2. Planting depth was 5 cm. Three seeds were planted per station (basin) and then thinned out for 7 days post emergency to remain with one healthy plant per basin. The procedure was repeated in 2013 to 2014 growing season, where planting was done on 25 November on the same planting stations or basins.

Main agronomic practices done

Weeding

Weeding was done in all plots on the same day, whenever weeds appeared inside the basins. Within the field, areas without basins were also weeded, but less frequently in basins.

Top dressing

Split application of ammonium nitrate (34.5%N) fertilizer was done 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 9 weeks post emergence, instead of 8 weeks. This was due to lack of moisture at that stage. Ammonium nitrate application rate was 90 $kgha^{-1}$

Assessing growth rate and yield adaptability factors

Measurements of growth parameters

Leaf length and plant height for each cultivar were taken from four replicates/plots for each treatment at every two week interval (from 07/12/2013 and 07/12/2014/2015), from 2 weeks post emergence up to 10 weeks post emergence. Four plants from the center row of each plot were measured and the data were averaged. Leaf number 5 was measured for each plot. This measurement determines growth.

Harvesting and measurement of grain yield

Performance evaluation was done over 18 weeks from day of planting of each cultivar. Grain weights of the two maize cultivars P2859W and PHB3253 were recorded in tha^{-1}on a digital scale after harvesting at 14% moisture content. A grain moisture tester meter was used after drying and shelling. All plants from each plot were measured and the data was recorded and averaged.

Data analysis

Data was analyzed by comparing means of growth rate as well as grain yields of the two cultivars using "t"-test. Least significance difference (LSD) was used to separate differences between treatments. Analysis was done at 5% significance level.

RESULTS

Growth rates of PHB3253 and P2859W

P2859W had a plant height of 73 cm while PHB3253 had 75.2 cm when measured at 2 to 10 weeks (Table 3). The percentage (%) difference was 3. The results for leaf length showed that P2859W had growth of 61.4 cm and PHB3253 had a growth of 63.5 cm for 10 weeks (Table 4). The percentage (%) difference was 3.3. PHB3253 had slightly greater leaf length than that of P2859W and also had significantly ($p<0.05$) greater growth than P2859W.

Grain yields of P2859W and PHB3253

The harvest was done on 20/03/2015. Table 5 shows the yield for each of the two cultivars. The total of P2859W was 2.66 tha^{-1} and PHB3253 was 3.51 tha^{-1}. There was a

Table 5. Total grain yields of P2859W (treatment 1) and PHB3253 (treatment 2) obtained at Mrs Mboto's plot.

Treatment	Replication	Grain yield (kg 100 m^{2-1})
1	1	6.6
1	2	6.9
1	3	8
1	4	5.1
Total		26.66
2	1	9.1
2	2	10
2	3	7.8
2	4	8.2
Total		35.18
Expected yield		37.8
Difference of the two treatments totals		8.5

significant difference (p<0.05) on grain yield. Results showed that PHB3253 had higher yield than P2859W (Table 5). The percentage difference was 24.2 %. Each yield level was obtained from an area of 200 m^2.

DISCUSSION

Growth rate of P2859W and PHB3253 (plant height)

The study shows that PHB3253 had a mean plant height of 75.2 cm while P2859W had 73 cm (Table 3). This is in agreement with the study of Rockstrom et al. (2009) who reported that PHB3253 is more adaptable; is more droughts tolerant; uses nutrients more efficiently; grows taller than most short season cultivars in dry areas. Growth for the two cultivars was almost the same for the first two weeks. As from week 6 to week 8, PH3253 had faster growth than P2859W. This could have been due to the advantage of the better height which could enhance efficient trap and use sunlight for effective growth. Basins had soil amendments which include ammonium nitrate. According to the literature, ammonium nitrate increases the growth of a more adaptable cultivar than a non-adaptable cultivar in a particular area (Sawi, 1993).

Comparing growth of P2859W and PHB3252 (leaf length)

Leaf length for both treatments was almost the same for the first 6 weeks. There was a slight difference as from week 8 to 10, although statistically insignificant (p>0.05) to the parameter was measured. If PH3253 had better growth than P2859W then, it will have greater leaf length as well as height and leaf which have proportional growth (Vanlalhluna and Sahoo, 2011). However, in the current study, PH3253 plant height did not really influence leaf length as much as P2859W. This could have been influenced by the genotype of the cultivar. This is in harmony with the work of Muchow and Sinclar (1994) which revealed that, there is a genetically determined upper limit to leaf growth when inorganic fertilizers and manure have been applied.

Determining grain yield of P2859W and PHB3253

PHB3253 produced greater grain yield (3.51 tha^{-1}) than P2859W (2.66 tha^{-1}) (Table 5). Statistical results also showed that PHB3253 had significantly higher yields (p<0.05). One of the reasons which contributed to better yields was of better height which had better potential of capturing more sunlight for photosynthesis than the shorter cultivar P2859W. The total biomass built from the superior height help in reducing runoff, evapo-transpiration, (Jerie and Mugiya, 2010), and also helps generate more shade which conserves moisture. High runoff levels, high drainage, and high evapo-transpiration rates contribute about 60 to 70 % loss of water from a rainfall event, (Jerie and Mugiya, 2010), hence highly recommended techniques combined with conservative crop growth characteristics are needed to wisely utilize the scarce soil, water and nutrient resources available in semi-arid regions. PHB3253 has been reported in literature to be a high yielding, resource intensive hybrid maize cultivar which needs more water and more fertilizer (Mourice et al., 2014) with a high yielding potential of 5 to 8 tha^{-1}.

Results indicate that there is a positive relationship between maize grain yield and its components. This is in agreement with the study of Cross (1991) whose report clarified that high maize grain yield is attributed to longer and thicker cobs with many kernel rows. This researcher also agrees with the study of Heisey and Edmeades (1999), which suggest that, yields are higher in CA both in the year of drought and of good rains. This evidence was shown when PHB3253 yielded 5.2 tha^{-1}. In an experiment done, Kirway et al. (2000) found out that the potential yield of PHB3253 was 8 tha^{-1}. P2859W can yield 3.9 tha^{-1} in a drought year. Like PHB3253 (Mourice et al., 2014), P2859W is also known for its good yielding characteristic which is 5 to 8 tha$^{-1.}$ The cultivar is known for its average cob sizes with big kennels. The yields in various literatures can be in disagreement with the yields obtained in the current study because of the variations in the biophysical factors impacting on the type of cultivar(s) grown. Effect of basin tillage practice on yield can also 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).

The fertilizer rates of 100 kgha^{-1} compounds D and 90 kgha^{-1} ammonium nitrate contributed much on the yield. The results of this research also agrees with those of Lowe (2011) who indicated that, CA reduces inputs costs, while yields are increased. In Guhune, mulch and manure were locally available. Finally, higher yields obtained under CA practices through good choice of a variety can improve the household food security of Guhune dryland.

Conclusion

The study compared growth and yield of two commonly and solely grown Pioneer short season cultivars in Guhune, to determine a more productive cultivar in the area. Growth and yield of PHB3253 were found greater than those of P2859W under basin technique. However, there was no significant difference between the leaf length of PHB3253 and that of P2859W. The study has shown that PHB3253 performs well under planting basin technique, implying that PHB3253 is more adapted to semi-arid conditions of Southern Africa as compared to P2859W.

Conflict of interests

The authors did not declare any conflict of interest.

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