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Evaluation of maize yield in flood recession farming in the Okavango Delta, Botswana

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Flood recession farming locally known as *molapo* farming in the Okavango Delta is practiced along the edges of the river channels or seasonally flooded depressions on its fringes. It relies on residual moisture and natural fertilization of the floodplains, and is promoted as being more productive than dry-land farming. However, the productivity of this low-input farming system has not been extensively investigated. The objective of this study was to evaluate the yield potential of hybrid maize (*Zea mays* L.) in *molapo* farming. Two *molapo* field experiments and one dry-land experiment were conducted at Matsaudi and Lake Ngami, and Shorobe, respectively, in a randomized complete block design with four replications. Maize grain yield and plant height were measured from six consecutive plants from the centre row. The results showed that maize grain yield and plant height were significantly ($P < 0.05$) higher at Lake Ngami than at either Matsaudi or Shorobe. Late planting at Lake Ngami coincided with rainfall in November providing even and abundant soil moisture which contributed to better productivity of maize. Similarly, soil fertility was also better at Lake Ngami. Maize grain yield although lower (2.41 t ha^{-1}) at Matsaudi and Shorobe (2.58 t ha^{-1}) than at Lake Ngami (3.4 t ha^{-1}), it is much higher than yields normally obtained by small-holder farmers in semi-arid zones in sub-Saharan Africa, where actual yields are often less than half of the potential yields. Similarly, plant height was significantly ($P < 0.05$) higher at Lake Ngami (235 cm) than either Matsaudi (194 cm) or Shorobe (192 cm). It could be concluded that timely planting of maize in *molapo* fields supplemented by rainfall is capable of producing better yields in semi-arid regions where water is the most limiting resource to crop production

Key words: Flood recession farming, dry-land farming, Okavango Delta, maize, yield.

INTRODUCTION

Flood recession agriculture involves reliance on moisture left in the soil as flood water recede (Barrow, 1999). It is based on residual moisture and natural fertilization of the floodplain. Many rivers around the world sufficiently large with seasonal flooding to support flood recession farming (Adams, 1993). In Southeast Asia, dry-season flood-recession rice is an ancient land-use system that, taking advantage of the fertile silt deposited by the annual floods, is both extremely productive and sustainable (Fox and Ledgerwood, 1999). In the Sahel, there is the river Niger in Mali and Lake Chad, and in semi-arid Africa, there is the Sudd in Sudan and the Okavango Delta

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in Botswana (Adams, 1993).

The Okavango Delta of northern Botswana is possibly the most pristine of Africa's large wetlands (Gumbricht et al., 2004; Kgori et al., 2006), and supports a major tourism industry and rural community livelihood (Gumbricht et al., 2004; Wolski and Murray-Hudson, 2008; Magole and Magole, 2009; Kgathi et al., 2012). It was declared a Ramsar site-a wetland of international importance in 1997 and was recently inscribed as a Natural World Heritage site in 2014. This wetland is supplied by the Okavango River, which flows from the tropical highlands of Angola into the Kalahari basin (Bauer et al., 2004). The river discharges about 10 km^3 of water onto the Delta each year, supplemented by about 6 km^3 of rainfall, which supports about 2500 km^2 of permanent wetland and up to 8000 km^2 of seasonal wetland (McCarthy, 2006).

Flood recession farming is an important livelihood activity for the poor riparian communities in Africa and some parts of Asia. This farming system provides moisture conditions similar to irrigated farming and utilises residual moisture retained within the root zones of crops. The unlimited moisture in flood recession farming makes it more sustainable and profitable as it produces more yield than dry-lands farming. It has no costs associated with inputs other than land and labour, and consequently, has a very high net return to energy expenditures (Saarnak, 2003). In the Ngamiland district of Botswana flood recession farming locally known as *molapo* farming is practiced along the edges of the river channels or seasonally flooded depressions on fringes of the Okavango Delta (Bendsen, 2002).

Planting of crops start in September when floods start to recede. Maize is the main crop grown in *molapo* farms, with secondary crops such as sweet sorghum, sorghum, beans, pumpkin and watermelons (Bendson, 2002; Vanderpost, 2009). Maize is the main staple food for countries in Southern Africa as people depend on it for more than half of their calorie intake (Setimela et al., 2010). In Botswana, it is the cereal most consumed and supplies a larger percentage of the daily calories in most of the diets of Batswana (Lekgari and Setimela, 2002). DAR (2011) report indicated that the total hectarage for Ngamiland was 9,899 hectares of which 10% (987) was under *molapo* farming. Yields from *molapo* farms, although lower than the potential yield, are much more than those obtained from dry-land farms (Molefe et al., 2014). In sorghum for instance, grain yield ranges from 1,800 to 2,900 kg ha^{-1} (Bendsen, 2002; Arntzen, 2005); whereas, under rain fed it can be as low as 121 kg ha^{-1}. Literature on maize grain yield in *molapo* farms is currently not available, probably due to the fact that most *molapo* farmers prefer to grow maize as a cash crop where it is sold as green mealies early in the season to get better price before produce from the dry-land farms enter the market.

The climate of the Okavango Delta makes *molapo* farming much more suitable and sustainable than dry-land farming in semi-arid savannah due to low (~490 mm) and erratic rainfall in the area (Molefe et al., 2014) with high potential evaporation of 2172 mm a^{-1} (McCarthy, 2006; Wolski and Savenije, 2006). In addition, most of the Delta is covered by infertile sandy soils with low moisture retention capacity (Mubyana et al., 2003; Motsholapheko et al., 2011). These harsh climatic conditions are the major causes of crop failure in semi-arid dry-land farming. Soils in *molapo* farms are fertile because of the annual deposits of organic matter and silt laid down by the retreating floods, and that partly explains why *molapo* farming is more productive than dry-land farming.

Molapo farming in the Okavango Delta is an important land use and the basis for subsistence livelihoods of the local poor and vulnerable communities (Motsumi et al., 2012) (Figures 1 and 2A, B and C). Despite its significant contribution to rural livelihoods, the productivity of *molapo* farming has not been extensively investigated. The objective of this study was to evaluate yield potential of maize in *molapo* farming.

Study area

The study was conducted in the Okavango Delta (Figure 3) situated in the northern part of Botswana. The Okavango Delta is a large (12 000 km2) alluvial fan formed by the Okavango River. The inundated area of the delta varies dramatically from year to year depending primarily on the rainfall in Angola (Kgomotso and Swatuk, 2006; Wolski and Murray-Hudson, 2006). The area covered by water expands from its annual low of 2500 to 4000 km^2 in February–March to its annual high of 6000 to 12000 km^2 in August–September (McCarthy et al., 2004). The variation is closely linked to rain fall in the catchment area of Cuito and Cubango rivers in central Angola, which respectively receives mean annual rainfall of 876 and 983 mm (McCarthy et al., 2000; Wolski and Murray-Hudson 2008). Local rainfall also contributes significantly to the delta with an annual average of 490 mm (Anderson et al., 2003; Gumbricht et al., 2004), and it falls in one distinct rainy season from November to March (Wolski and Savenije, 2006).

As stated earlier, the inundated area varies in size from year to year. This seasonality of inundation gives rise to three major hydro-ecological zones, namely: permanent swamp, seasonal (regularly flooded) floodplains and occasional floodplains (Wolski and Savenije, 2006). The seasonal floodplains are areas where *molapo* farming (Figure 2) is practiced (Oosterbaan et al., 1986).

The actual study sites were Matsaudi (19°49'31.2"S, 023°36'19.5"E) and Shorobe (19°44'34.8"S, 023°41'27.7"E) along the Thamalakane river and Lake Ngami (20°30'28.1"S, 022°47'06.7"E) (Figure 3). The sites were selected because of their contrasting hydrology. Lake Ngami is the terminal end of the

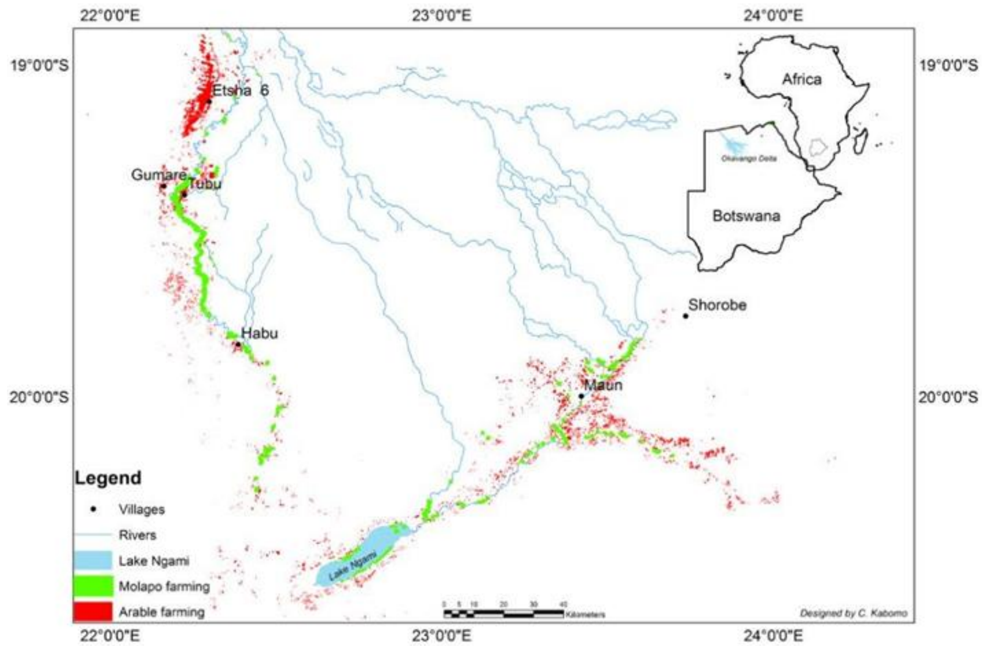

Figure 1. Map showing main *molapo* farming areas in the Okavango Delta (Chimbari et al., 2009).

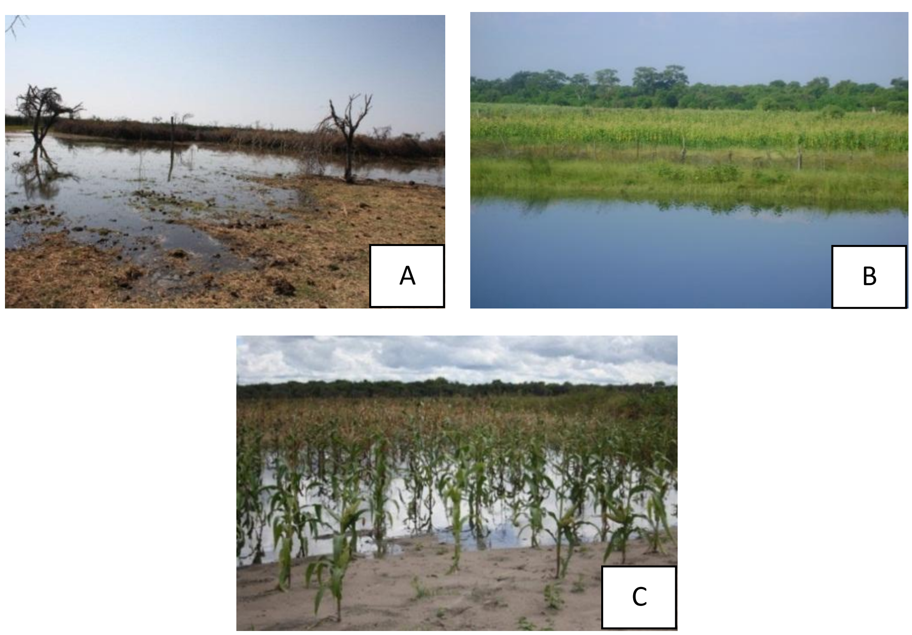

Figure 2. *Molapo* field flooded (A), maize in *molapo* field ((B), picture taken by Demel Teketay), and (C) flooded maize crop in March 2014. Pictures A and C taken by Keotshephile Kashe.

Okavango Delta and floods recede slowly from *molapo* fields resulting in late planting mostly in November. In Matsaudi, *molapo* fields are along the Thamalakane River and flood recession starts early giving farmers an opportunity to plant early in September.

Shorobe village is located in the lower part of the Okavango Delta. CSO, (2011) indicated that the population of Shorobe was 1,031. The local communities

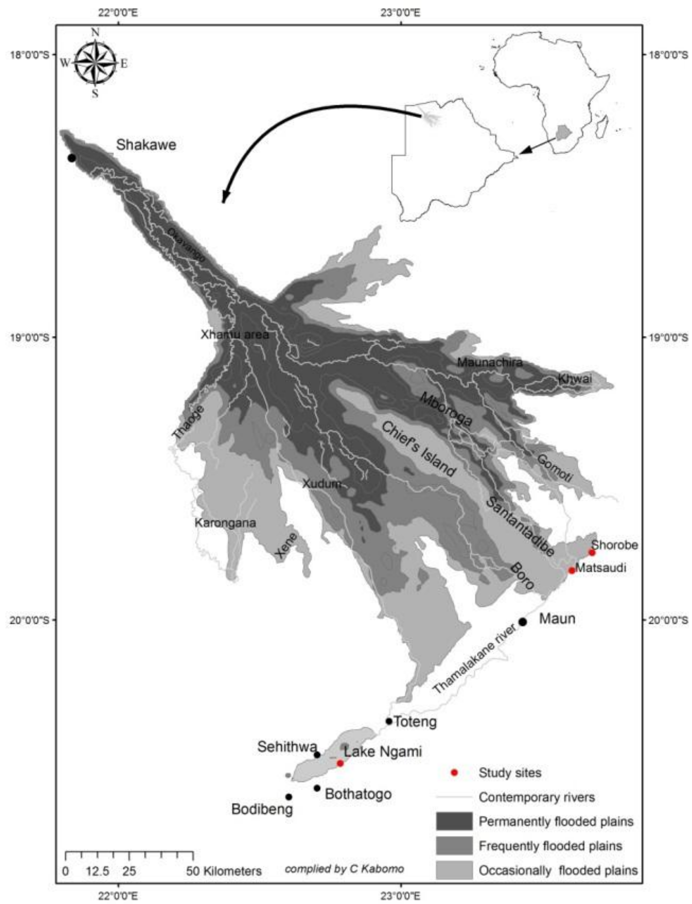

Figure 3. Map of Okavango Delta showing study sites.

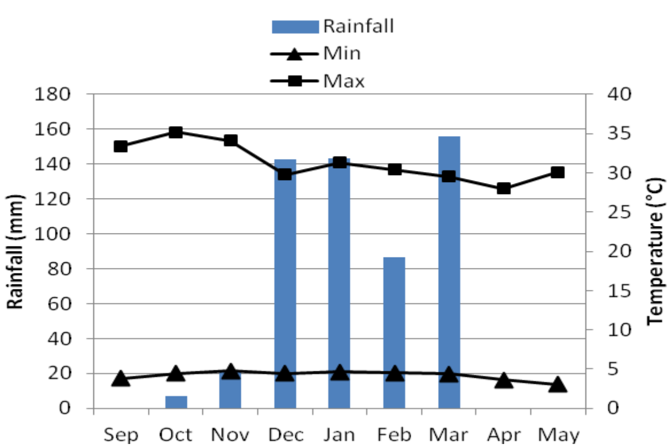

Figure 4. Monthly rainfall and mean monthly maximum and minimum temperature in Maun for 2013/14 crop growing season.

of this village sustained their living through basket-making, dry-land and flood recession (*molapo*) farming (Kgathi et al., 2007). Matsaudi is located on the eastern end of the Okavango Delta near Shorobe village. In 2011, its population was 345 (CSO, 2011). *Molapo* fields in Matsaudi are fed by the Santantadibe and Gomoti Rivers and backflow from the Thamalakane River. The main livelihood activities are *molapo* and dry-land farming, livestock rearing and fishing.

Lake Ngami occupies the south-west part of the Okavango Delta. It was originally fed by the Thaoge River, the western distributaries of the Delta. It last received inflow in 1989 and after a dry period has again since 2004, been receiving considerably inflow from Xudum distributary and is now considered its terminal portion (Wolski and Murray-Hudson, 2006). Lake Ngami is surrounded by three villages of Toteng, Bothathogo, Bodibeng and Sehithwa, with a population of 902, 555, 778 and 2 748, respectively (CSO, 2011). Livelihood activities for people in these villages include livestock rearing, *molapo* farming, dryland farming and fishing.

Climate

Maun and Sehithwa agro-meteorological weather stations were used as reference points for Matsaudi and Shorobe, and Lake Ngami respectively. Sehithwa station does not record maximum and minimum air temperature and uses Maun as its reference point. The hottest month during the crop growing season was October (35.4°C) and coolest was May (26.2°C) (Figure 4). The long-term (2004/2005 to 2013/2014) average seasonal rainfall was 341.39 and 471.63 mm, and the mean seasonal rainfall was 578.50 and 556.9 mm for Sehithwa and Maun, respectively. There was a dry spell in Matsaudi prior to sowing in September with no rainfall and only 7 mm for the month of October (Figure 4). However, in Sehithwa, 15.4 mm was recorded prior to sowing in November and 137.2 mm in December (Figure 5).

Hydrology of the Thamalakane River

Flooding of *molapo* fields along the Thamalakane River in 2013/2014 season began in mid-June when the annual floods reach Maun and the water level in the river rose from 1.605 to a peak of 2.515 in September and dropped to 1.658 m in December (Figure 6) as the floods started to recede. The maximum inundation was reached by the end August and floods started to recede by the beginning of September allowing farmers to start ploughing and planting crops.

MATERIALS AND METHODS

Field operations

Land preparation at *molapo* fields (Lake Ngami and Matsaudi) was done by donkey drawn mouldboard plough, whereas, in dryland (Shorobe) it was by tractor drawn mouldboard plough followed by discing to level the soil before planting. Soil samples were collected before ploughing and the main chemical properties of the soil from

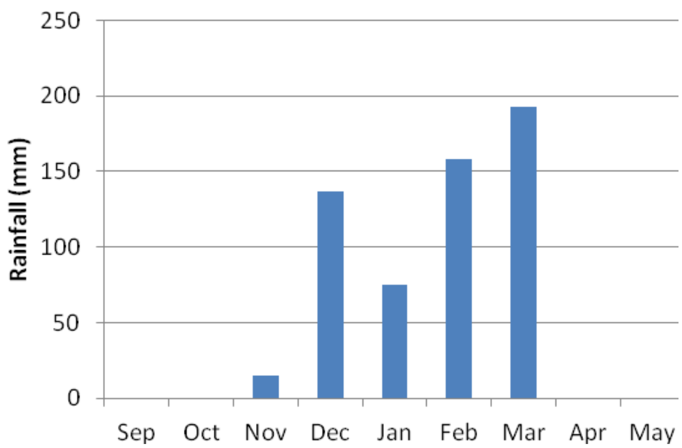

Figure 5. Monthly rainfall in Sehithwa for 2013/14 crop growing season.

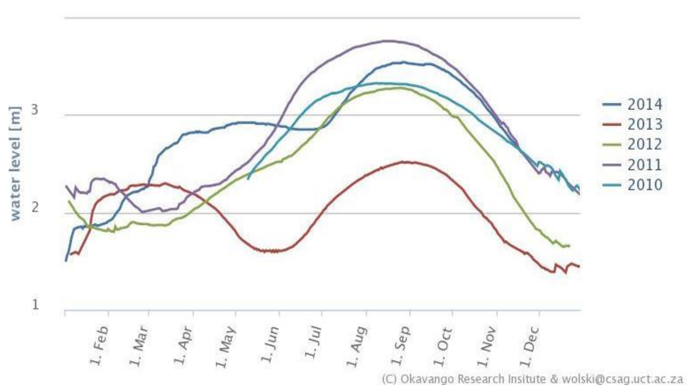

Figure 6. A graph showing water levels for the Thamalakane River for years 2010 to 2014.

the study sites were presented in Table 1. Maize hybrid (*Zea mays* cv. 'SC 403') was sown in 0.7 m rows at 60,000 plants ha^{-1} in a randomized complete block design with four replications on the 4th September, 15th November and 24th November 2013 at Matsaudi, Lake Ngami and Shorobe, respectively. No starter or post emergence fertilizer was applied. Weeding was done when necessary to maintain weed-free conditions until crops were harvested.

Data collection

Maize was harvested on the 5th January, 27th March and 4th April 2014 at Matsaudi, Lake Ngami and Shorobe, respectively. Measurements were taken at harvest. For plant height and grain yield, six consecutive plants from the centre row were randomly selected. Plant height was recorded in the field and was considered to be that of the highest leaf.

Statistical analysis

Data were analyzed using the statistical software R i386 3.0.1. Diagnostic plots were used to check the homogeneity of variance and normality of data for each response variable. Data for plant height and maize grain yield were compared using means and standard errors and represented as standard error bar plots.

RESULTS

Maize plant height and grain yield were significantly higher ($p < 0.05$) in *molapo* field at Lake Ngami compared to the other *molapo* field at Matsaudi and dryland field at Shorobe. Maize plants at Lake Ngami were taller (235 cm) than at Matsaudi (194 cm) and Shorobe (192 cm), which exhibited no significant difference (Figure 7). Similarly, grain yield was greater (3.40 t ha^{-1}) at Lake Ngami than at Matsaudi (2.4 t ha^{-1}) and Shorobe (2.58 t ha^{-1}) (Figure 8).

DISCUSSION

Overall, maize yields were significantly greater in *molapo* field at Lake Ngami than at the other *molapo* field at Matsaudi and dryland field at Shorobe. The variation in the yields between the three sites can be attributed to the difference in the temporal distribution of rainfall. Late planting at Lake Ngami (November) coincided with abundant rainfall resulting in even and unlimited moisture from planting to physiological maturity. The unlimited supply of soil moisture contributed to the growth and development of maize plants, which increased biomass and ultimately grain yield. Early planting at Matsaudi (September) with no rainfall and only 7 mm in October meant that the crop relied only on residual moisture in the floodplains.

Maize grain yield and plant height were significantly higher at Lake Ngami than at Matsaudi and Shorobe, with the latter two having no significant differences. The grain yield was 3.40, 2.41 and 2.58 t ha^{-1} at Lake Ngami, Matsaudi and Shorobe, respectively. These values are comparable to what Setimela et al. (2010) found for the same hybrid (SC403) under dry-land farming in Botswana. The grain yield in dry-land was, however, similar to *molapo* farms in Matsaudi, contrary to earlier findings by Molefe et al. (2013). The difference in the performance of maize can be associated with rainfall distribution in time. Lake Ngami and Shorobe received more rainfall (152 mm) from planting to flowering (November and December 2013), whereas, Matsaudi received nothing in September and only 7 mm in October 2013. The difference in the yields could be explained by this variation in the distribution of rainfall. Water availability is important during the maize's critical growth stages; flowering (55 to 65 days after planting) and grain filling (75 to 95 days after planting). Maize is very sensitive to moisture stress during these critical stages (Li-Ping, 2006). Maize at Matsaudi received a meagre 7 mm of rain during the critical growth stages. The period of time when maize experiences moisture stress may be more critical to grain yield than season-long deficits (Dalley et al., 2006). Considering that only 7

Table 1. Chemical properties of soil at the study sites.

Site	pH ($CaCl_2$)	P (ppm)	Ca cmol+/kg	Mg cmol+/kg	K cmol+/kg	Na cmol+/kg	CEC cmol+/kg
Matsaudi	5.9	11.9	1.14	1.05	0.18	0.01	2.37
Shorobe	6.3	11.5	1.11	1.31	0.25	0.01	2.67
Lake Ngami	5.6	62.9	7.16	8.82	1.42	0.06	17.40
Optimum levels	>6	>10	>1.00	>0.30	>0.10	<1.00	>2.50

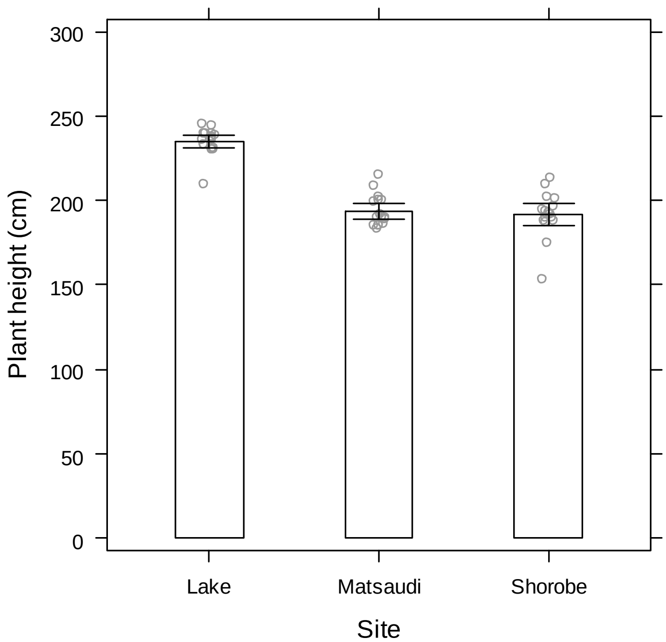

Figure 7. Maize plant height at Lake (Lake Ngami), Matsaudi and Shorobe. The columns show the mean. The circles represent the data points. The error bars show the standard error of the means.

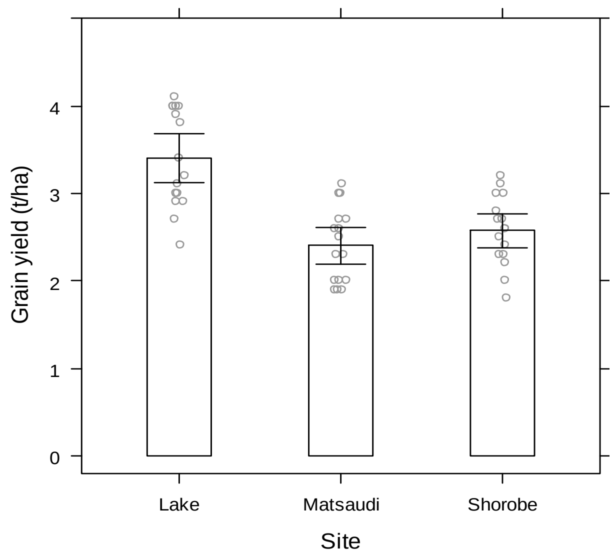

Figure 8. Maize grain yield at Lake (Lake Ngami), Matsaudi and Shorobe. The columns show the mean. The circles represent the data points. The error bars show the standard error of the means.

mm of rainfall was received in October 2013 during the period when maize was tasselling, this might have affected yield formation stages. Crop yield depend on the magnitude and timing of the total crop available water, which includes effective rain and available soil water at planting (Payero et al., 2009). Maize grown in arid and semi-arid is often limited by variation in the amount and frequency of rainfall (Pandey et al., 2000).

Water stress can negatively affect growth, development, and physiological processes of maize plants, which can reduce biomass and ultimately, grain yield (Payero et al., 2009), due to a reduction in leaf area (Pandey et al., 2000), shoot growth (Stone et al., 2001) and number of kernel per ear or the kernel weight (NeSmith and Richie, 1992; Traore et al., 2000).

Soil fertility is also important for crop production as much as water. Chemical soil analysis indicates that Lake Ngami was higher in all the nutrients analysed than Matsaudi and Shorobe. Better soil fertility at Lake Ngami contributed to greater grain yield and plant height. In most regions of North China, water scarcity and soil infertility were reported as the two critical factors limiting maize grain yield (Zou et al., 2008; Wang and Li, 2010).

While maize at Matsaudi and Shorobe performed less than at Lake Ngami, the grain yield observed (2.41 and 2.58 t ha^{-1}, respectively) is within the range of 1 to 5 t ha^{-1} reported by SeedCo Seeds (2014) for this hybrid. These values are also higher than yield values normally obtained by small-holder farmers in semi-arid zones in sub-Saharan Africa (SSA), where yields are often less than half of the potential yields (Barron and Okwach, 2005). The low yields in small-holder farming are generally associated with low and unreliable rain fall, and limited application of fertilisers. Starter fertilizer can stimulate early growth and improve maize yield (Vetsch and Randall, 2002; Niehues et al., 2004).

Conclusion

The results showed that maize plant height and grain yield were significantly superior in *molapo* field at Lake Ngami compared with the other *molapo* field at Matsaudi and dryland field in Shorobe. The superior performance in *molapo* field at Lake Ngami was generally associated with late planting supplemented by rainfall and better nutrients status. While maize grain yield was lower at Matsaudi and Shorobe, it was higher than yields normally obtained by small-holder farmers in semi-arid zones in sub-Saharan Africa, where yields are often less than half of the potential yields. Based on these results, we conclude that maize hybrid SC 403 when timely planted in *molapo* fields and supplemented by rainfall is capable of producing better yields in semi-arid regions where water is the most limited resource to crop production. Finally, the investigation of the effects of planting date on yield of crops in *molapo* fields is recommended.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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