Effect of Planting Basin Depth on the Growth and Performance of Maize (Zea mays)

Parwada Cosmas, Karavina Charles, Kamota Agathar, Mandumbu Ronald and Marova Rich

Department of Crop Science Bindura University of Science Education  P.Bag 1020 Bindura Zimbabwe
Corresponding Author email: cparwada@gmail.com

ABSTRACT

There is low adoption rate of basin tillage in Zimbabwe due to many factors but the incorrect planting basin depth is among the major factors. The blanket recommendations on the basin depth dimensions, have led to poor crop stand and consequently food insecurity. A research was carried out in Marondera, at Horticulture Research Centre Zimbabwe to determine the effects of planting basin depths on plant height, stem girth and above ground yield of maize. The research aimed at helping farmers to have clear information on the planting basin depth to adopt so as to have a good crop stand and performance in order to get higher yields and increase food security. A one factorial experiment was carried out in complete randomised block design (CRBD) using planting depth as a factor and different planting depths of 6cm, 12cm, 18cm and 24cm, as the factor levels. The treatments were replicated four times. The results showed that there was significance difference (P<0.05) in both plant height, stem girth and above ground matter yield due to planting basin depth from week 4 to week 12 after emergency. Planting basin depth of 24cm had the tallest plants, largest girth and highest above ground matter compared to a shallower depth of 6cm, which had the least performance. Farmers are therefore recommended to adopt a planting basin depth of 24cm and if not, they should not prepare their planting basin depth shallower than the recommended 12cm, but where labour is available; a deeper basin (deeper than 12cm) should be used for improved yield.

Key words: basin depth, tillage, yield, adoption, plant height, stem girth

Background

Maize (Zea mays), is an important food crop world over. It is a coarse leafed annual grass which originated from Central America (Mexico) and spread to Africa in the 16th century by the Portuguese (Rukuni et al, 2006). In Zimbabwe, it was introduced in the 18th century, where to date about 70% of the land is under maize production by the small holder farmers (The Conservation Farmer, 2009). According to Balasurbramaniyan and Palaniappan (2004), the crop is a warm weather plant that requires average temperatures of about 24°C during the growing period. Low temperatures reduce growth and extremely high temperatures may retard germination of seeds, particularly when it is combined with deficient moisture. High temperature above 35°C is more injurious to the plant at tasselling stage and its soil pH range is 5.5 - 6.5 on a calcium chloride scale (FAO, 2011).

Today, maize ranks first in terms of the number of producers, area grown and total cereal production in Zimbabwe (Rukun et al, 2006). In Zimbabwe, the economic importance of maize, as the staple crop is essentially its nutritive value and has displaced most indigenous cereal crops such as sorghum (Sorghum bicolor), since it is prepared and consumed in a variety of ways. According to Balasurbramaniyan and Palaniappan (2004) maize can be prepared and consumed in a wide variety of ways while sorghum and millets have very limited uses and the flour from them is more difficult to prepare. Maize is a raw material for a number of products such as starch and other by-products which have application in industries such as alcohol (The Conservation Farmer, 2009). Maize stover is a very important source of livestock feed during the winter months, the other cereals produce less amounts of stover which is of poor quality (Hobbs, 2007). Some sorghum and millets are very susceptible to bird damage and are labour intensive at harvesting and processing, while maize is easier to grow and is higher yielding and more so, it is an income earner for the commercial and small holder farmers. The maize industry is one of the mainstays of agriculture and of the national economy itself, as it contributes to food security (Shimbo, 2008).
Generally, Zimbabwe has made notable progress towards recovering its self-sufficiency in the production of this national staple crop. According to the macro-economic report and recovery plan (Zimbabwe Ministry of Finance, 2012) maize output expanded in the 2008-2009 season after years of decline with estimated production of 1.2 million metric tonnes of maize in the most recent season, compared with fewer than 60 000 metric tonnes in 2007-2008 and less than 1 million tonnes in the 2006-2007 cropping season. The macroeconomic plan targets double-digit growth in agricultural output in the 2012 period through, among other measures, guaranteeing security of tenure on farmland to farmers to overcome uncertainty, facilitate access to credit and improve investment, mechanisation and irrigation of which not all the poor resource farmers have access to these measures.

Unfortunately, according to Rohrbach et al, (2004, 2005) in the drier areas of Southern Africa and Zimbabwe in particular, farmers experience drought once every two to three years. Relief agencies have traditionally responded to the resulting famines by providing farmers with seed and fertilisers to enable them re-establish their cropping enterprises. However, farmers are not able to translate these investments into sustained gains in productivity and incomes leading to food insecurity and hunger.

To improve crop production in the marginal rainfall regions of Zimbabwe, farmers have to adopt new technologies that conserve fragile soils and extend the period of water availability to the crop, be it grain or forage (Gollifer, 1993; Twomlow and Hagmann, 1998), so this has called for the need to adopt Conservation Agricultural (CA) practices as an appropriate technology that can address some of the underlying crop management problems faced by farmers in the country.

Conservation agriculture is defined as tillage sequences that minimises or reduce the loss of soil and water; and operationally is tillage or tillage and planting combination, which leaves at least 30% or more mulch or crop residue cover on the surface (Twomlow et al, 2006). The following CA techniques have been evaluated and actively promoted in Zimbabwe since 1980s: such as no till ridging, mulch ripping, no strip ripping, clean ripping or zero till (Muphangwa et al, 2006; Twomlow et al, 2006). These have been promoted in combination with mechanical structures such as graded contour ridges, infiltration pits, fanya juus and other structures (Mupangwa et al, 2006), such as planting basins.

Planting basins falls under the central component of the basin tillage. Seeds are sown not along the furrows, but in small basins or simple pits (Twomlow and Hove, 2006). These basins can be dug with hand hoes without having to plough the field. Unfortunately these planting basins, whose cutting depth still commands a huge challenge to the smallholder farmers, has led to poor performance and low yield of crops grown. Currently, there is no a commonly agreed basin depths dimension among the CA promoter to use as a standard by the smallholder farmers. The CA promoters are approaching farmer with conflicting different basin depth dimensions, for example, the ZCATF is advocating a depth of 15 cm and the Foundations for farming is using a basin depth of 12 cm as standards.

The research was to get clear information on the planting basin depth to be used by farmers aiming to increase crop yield from the basin planting methods among the farmers. Increased crop yield will lead to food security among the farmers. In order to achieve this, a study to determine the effect of different planting basin depths on growth and performance of maize was done with specific objectives to: (1). determine the effects of planting basin depth on plant height and stem girth at 2 weeks interval from 4th week post emergence to the 12th week and (2). determine the effects of planting basin depth on quantity of the above ground dry matter.

Materials and Methodology

Study Site

The research was carried out at Horticulture Research Centre in Marondera, Zimbabwe (altitude 1 630m, latitude 18°11’S, longitude 11°33’E). It is located 65 km along Harare-Mutare road and lies in the agro ecological natural region (NR) IIA. According to Vincent and Thomas, (1960) this area receive an annual rainfall of 750 to 1 000 mm/year and average temperatures of about 25°C-30°C. The rainfall is fairly reliable, falling from November to March/April. The soils vary from greyish brown sands to sandy loams derived from granite rocks, which have moderate to low available water holding capacity. They have a pH range of 4.0 to 4.3 on the Calcium Chloride Scale. Natural Region IIA is suitable for intensive cropping and livestock production. The cropping systems are based on flue-cured tobacco, maize, cotton, wheat, soybeans, sorghum, groundnuts, seed maize and burley tobacco grown under dry land production. Irrigated crops include wheat and barley grown in the colder and drier months (May-September). More so, conservation farming is being practised in areas like Goromonzi district where a total of 941 poor resource smallholder farmers are being supported by CADS, 131 unsupported farmers in Marondera and in Uzumba-Maramba-Pfungwe (UMP) with a total of 3 388 farmers are supported by Catholic Relief Services (CRS) (Agritex Provincial Records-Mashonaland East, 2012). The livestock production is based on pastures and pen-fattening utilizing crop residues and grain. The main livestock production systems include beef, dairy, pig and poultry. The vegetation varies, but the Julbernadia tree species are dominant in the area indicating suitability of the soils to crop production, with the Hypeperenia grasses scattered all over.
Rainfall Distribution
The station recorded an amount of 644.3mm of rainfall for the year 2012 to 2013. The rainfall received for the growing season between 2010/11, 2011/12 and 2012/13 dwindled from 1 095.1 mm, 710.4mm and 644.3 respectively, as shown in the table 1 below.

### Table 1. Rainfall distribution.

<table>
<thead>
<tr>
<th>Cropping season</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010/2011</td>
<td>51.2</td>
<td>220.5</td>
<td>253</td>
<td>120.6</td>
<td>180.4</td>
<td>190.8</td>
<td>78.6</td>
<td>1 095.1</td>
</tr>
<tr>
<td>2011/2012</td>
<td>81.5</td>
<td>108.1</td>
<td>114.2</td>
<td>141.2</td>
<td>139.8</td>
<td>104.0</td>
<td>21.6</td>
<td>710.4</td>
</tr>
<tr>
<td>2012/2013</td>
<td>23.5</td>
<td>31.3</td>
<td>80</td>
<td>290.0</td>
<td>62.4</td>
<td>98.8</td>
<td>58.3</td>
<td>644.3</td>
</tr>
</tbody>
</table>

Experimental Design and Treatments
Randomised Complete Block Design (RCBD) with four treatments, replicated four times was used in this study. The treatments were four different planting depths (depths of 6cm, 12cm, 18cm and 24cm). There was one factor making the design a one factorial in a RCBD (Table 2).

### Table 2. Treatments

<table>
<thead>
<tr>
<th>Factor</th>
<th>Treatment / Factor level</th>
</tr>
</thead>
<tbody>
<tr>
<td>T - 1</td>
<td>Planting Depth</td>
</tr>
<tr>
<td>T - 2</td>
<td>Different planting depths ( length , width , depth )</td>
</tr>
<tr>
<td>T - 3</td>
<td>12cm x 12cm x 18cm</td>
</tr>
<tr>
<td>T - 4</td>
<td>12cm x 12cm x 24cm</td>
</tr>
</tbody>
</table>

The blocking factor was the slope of the land. The land had a gross area of 18m in length and 18m in width, giving an area of 324m². The net area was 12m in length and 12m in width, giving an area of 144m². A 2m space was left between blocks and 1m between plots in the blocks.

A maize variety (P2853W) was used. It is a short season Pioneer Hybrid and is commonly grown by the farmers in the area of study.

Basin Preparation
The land used had been weeded before digging the planting basins. Basins of different depths were marked out using hoes on 15 November 2012. A 9m² plot with 5 in-rows and 4 interrows spacing, giving a total of 20 basins were made. The interrow spacing of 75cm and in row spacing of 60cm was used (recommended NR 11 conservation farming spacing) (ZCATF, 2009). The total experimental area had 320 planting basins. A total of 40grams of manure was applied to each basin and mixed with soil (ZCATF, 2009). Three seeds were sown per basin on 12 December, 2012.

Thinning and Fertilizer Application.
Thinning was done at 2-3 weeks after the seeds had emerged by removing the weakest seedling, leaving 2 seedlings per basin. Top dressing fertiliser of Ammonium Nitrate (A.N) was split applied, first on 04 January 2013 when plants where at knee height (4 – 6 weeks), at a rate of 9g/station. The second application of the same rate was done on 04 February 2013, giving an equivalence of 80kg/ha Nitrogen to be applied (ZCATF, 2009).

Data Collection
Plant Height
There were 16 plots and each had a total of 40 plants. A tape measure was used in determining height of 10 plants, randomly selected in each plot. Height of the selected tagged plants (plants numbered 1 - 10), was taken from the base of the plant to the apical leaf tip, at 2 weeks interval from the 4th week post emergence to the 12th week. The height was summed up and mean height obtained by dividing by 10, using the formula below:

$$\frac{HP_1 + HP_2 + HP_3 + \ldots + HP_{10}}{10}$$

Where HP is the height of the plant
HP_1 + HP_2 + \ldots + HP_{10} - Height of plant numbered 1 to plant numbered 10 and
10 - Selected plants in each plot.
Plant Girth

Girth of the selected tagged plants (plants numbered 1 - 10), was taken from the circumference of the stem, at 2 weeks interval from the 4th week post emergence to the 12th week using a string. The string was then measured on the 30cm ruler to determine the graduations. The girth was summed up and mean girth obtained by dividing by 10, using the formulae below:

\[ \text{GP}_1 + \text{GP}_2 + \text{GP}_3 + \ldots + \ldots + \text{GP}_{10} \]

\[ \frac{\text{10}}{\text{10}} \]

Where GP - is the girth of the plant
GP1 + GP2 +···+ GP10 - Height of plant numbered 1 to plant numbered 10 and
10 - Selected plants in each plot.

Above Ground Matter Yield

Biomass in terms of the above ground matter was measured, using a balance scale. Calculations were done using the total yield per plot (g) and area per plot (m²). It was then converted to tonnes per hectare, the formulae below:

Above ground matter yield (t/ha) = yield per plot (g)/900

Data Analysis

Genstat Discovery edition was used for data analysis. The analysis of variance (ANOVA) was used to determine the planting basin effect on the growth and performance of maize. Least Square Difference (LSD) was used to separate the means at 95% level of significance where there was significant difference. The following factorial model was used in the analysis:

\[ Y_{ijk} = \mu + B_i + T_j + E_{ij} \]

Where \( Y_{ijk} \) = Observed yield
\( \mu \) = Sample / overall mean
\( B_i \) = Effect of block
\( T_j \) = Effect of treatment
\( E_{ij} \) = Error

Results and Discussion

The area where the study was done received an average rainfall of 644.3mm for the whole 2012/2013 cropping season (Horticultural Research Station-Marondera, 2013). Generally, besides declining trend of rainfall (Table 1), according to Vincent and Thomas (1960) the region receives an average amount of 750 to 1000mm per annum. Twomlow and Hove (2006) cited that CA should be practiced in areas receiving less than 1000mm of rainfall per year, hence the suitability of the area to be put under this practice of basin tillage. According to Troit (2012) maize crop needs 450 to 600mm of water per season, which is mainly acquired from the soil moisture reserves. But Bagchee (1994) postulated that for maximum production a medium maturity grain crop requires between 500 to 800mm of water depending on climate. The amount of rainfall that was received (644.3mm) has seen part of it being used by the crop for maintenance of its height, stem girth and above ground matter yield.

Plant Height

<table>
<thead>
<tr>
<th>Basin depth(cm)</th>
<th>4WAP</th>
<th>6WAP</th>
<th>8WAP</th>
<th>10WAP</th>
<th>12WAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>11.26a</td>
<td>33.10a</td>
<td>41.66a</td>
<td>85.59a</td>
<td>131.50a</td>
</tr>
<tr>
<td>12</td>
<td>15.14b</td>
<td>25.15b</td>
<td>56.85b</td>
<td>99.52b</td>
<td>139.20b</td>
</tr>
<tr>
<td>18</td>
<td>19.05c</td>
<td>48.25c</td>
<td>77.76c</td>
<td>114.60c</td>
<td>158.30c</td>
</tr>
<tr>
<td>24</td>
<td>24.29d</td>
<td>54.22d</td>
<td>96.35d</td>
<td>125.61d</td>
<td>178.15d</td>
</tr>
</tbody>
</table>

P-value <0.001 <0.001 <0.001 <0.001 <0.001
s.e.d 0.341 1.244 2.193 1.750 4.076
L.S.D 0.772 2.814 4.962 3.959 4.721

WAP - Weeks after planting
LSD - Least Significant Difference
s.e.d - Standard error for differences
Means followed by different superscripts on columns are significantly different at P<0.05

There was a significance difference (P<0.05) plant height due to planting basin depth from week 4 to week 12 after emergency. Plant height increased as the planting basin depth increased (Table 3). Planting basin depth of 24cm had the tallest plants and the planting basin depth of 6cm had the shortest plants. This could have resulted as the difference in water retention capacity among the basin of different depths. The planting basin depth of 24cm was most efficient and much of the water was
collected that supported plant growth, hence tallest plants. Furthermore, less amount of water could have been collected and reserved for plant use on the planting basin depth of 6cm, thus the plants were the shortest. This is supported by Rohrbach et al. (2004, 2005) who cited that shallow depths have lower water retention capacities, as they do not increase the amount of water to be stored in the soil profile like deeper depths which extends the period of water availability to the crop, be it grain or foliage.

Additionally, root systems differ in total length, depth of penetration, lateral spread and root density at each depth. The short plants were obtained from planting basin depth of 6cm. This could be attributed to extended time needed by the plants to push their shoots down the soil surface or the plants relied only on immobile nutrients, as they are available in surface horizons and did not maximise mobile nutrients. This is supported by Harvlin et al. (2008) who postulated that roots penetrate deep to rescue mobile nutrients and tap subsoil water.

Furthermore, planting basin depth of 24cm could also have increased the rooting radius of the crop, such that it was not limited in terms of plant mineral and nutrient extraction from the soil. The roots maximised both mobile and immobile nutrients, as the roots managed to rapidly extend the rhizosphere depletion zone with minimal cost and energy. This is in line with Aikins and Afuakwa (2008) who indicated that if the root growth is not restricted, the root system of a mature plant extends approximately 1.5m laterally and downwards to approximately 2.0m or even deeper and more roots will have more numerous root hairs, which increase root surface area that is exposed to the soil and play an important role in absorption of water and nutrients.

On the planting basin depth of 6cm, there was no root branching and hence roots probably failed to extend to the depletion zone, so did not have enough nutrients to support the plants.

Lastly the results showed that the planting basin depth of 24cm produced the tallest plant, biggest girth and high above ground matter yield. This was followed by 18cm, 12cm and 6cm respectively. These results are also similar to those of Aikins and Afuakwa (2008) who found that, though it was on small seeds, sowing cow pea at a basin depth of 5cm resulted in optimum growth and yield while 2cm and 3cm did not give good yield.

**Stem Girth**

<table>
<thead>
<tr>
<th>Basin depth(cm)</th>
<th>4WAP</th>
<th>6WAP</th>
<th>8WAP</th>
<th>10WAP</th>
<th>12WAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>2.550&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.330&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.250&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.547&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.670&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>12</td>
<td>2.935&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>4.718&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.125&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.495&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.595&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>18</td>
<td>3.312&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.050&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10.212&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10.412&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10.550&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>24</td>
<td>3.750&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.285&lt;sup&gt;d&lt;/sup&gt;</td>
<td>10.935&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11.670&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11.898&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

P-value: <0.001<sup>a</sup> <0.001<sup>b</sup> <0.001<sup>c</sup> <0.001<sup>d</sup>

Means followed by different superscripts on columns are significantly different at P<0.05

Stem girth was significantly affected (P<0.05) by planting basin depth. The stem girth was directly proportional to the planting depth. Deeper basins had thicker stems than shallower basins (Table 4). This might be due to that planting basin depth of 24cm, which had the biggest stem girth, provided more water and nutrients that supported the crop. The planting basin depth of 6cm produced smaller and thinner stem girth and this could probably be attributed to inadequate moisture and inadequate nutrients the plants received, as plant roots were confined to a small area and did not maximise mobile nutrients from deeper horizons. This is supported by Aikins and Afuakwa (2008) who cited that top shallow planting depth results in thin germination and smaller girth due to inadequate soil moisture at the top soil layer.

**Above Ground Matter Yield.**

There were significant differences on above ground matter yield (P<0.05) from week 4 up to week 12 after planting. Lowest yield was obtained on the planting basin depth of 6cm and highest on the planting basin depth of 24cm (Figure 4.1). This could that deeper basin (> 12 cm) had high biomass accumulation as the depth provided a large area for resources that promoted efficient physiological processes such as photosynthesis to occur. This is in congruent with Troit (2012) who indicated that maize is an efficient of water user in terms of dry matter. More so, on the planting basin depth of 24cm produced tallest plants than the other depths (Table 3). These tallest plants provided more biomass, hence high above dry matter yield was obtained on this depth. This is in tandem with Twomlow and Hove (2004) who indicated that height is proportional to yield, be it biomass or grain. This could be the case under the planting basin depth of 24cm, which produced taller plants.
On the planting basin depth of 6cm, the lower yields could have been attributed to a reduced root zone such that the roots were restricted on the area to obtain growth requirements. Hence were growth requirement limited and resulted to low biomass accumulation. This is supported by Harris (1996) who cited that seeds take time to establish if planted at a shallower depths and this reduce the biomass yield.

![Figure 4.1](image)

**Figure 4.1**. Effects of planting basin depth on above ground matter yield.

P<0.05

**Conclusion and Recommendations**

Plant height and stem girth were directly proportional to the planting basin depth. Deeper basins had taller and thicker stemmed plants. Height and stem girth were also increasing with time. The above ground matter yield did increase as the planting basin depth increases. The greater the planting basin depth the greater of the above ground matter produced. Planting basin depth of 24cm are effective on growth and performance of maize and can be an innovation that can be recommended to the small holder farmers to adopt, so as to counter dry spells and mid seasons drought, in order to increase food security in the face of increasing population and land degradation.

In general farmers who practice basin tillage should deeper than 12 cm so as to increase maize production. They should not prepare their planting basins shallower than 12cm, and where labour is not limiting a deeper basin (deeper than 12cm) is more ideal.

There is need to carry out more researches on the use of planting basin depth in other agro-ecological regions of the country to establish which planting basin depth best suit the smallholder farmers, in the regions they are carrying out their farming activities.

To the other prospective researchers, it is recommended that further studies on basin tillage should be done on production of other crops (sunflowers, tomatoes, potatoes and sorghum) other than maize.

**References**


