Response of bambara groundnuts \textit{[Vigna subterranea \{L.\} Verd]} to inter-row spacing in Swaziland

O. T. Edje and E. K. Mavimbela
Crop Production Department, Faculty of Agriculture, University of Swaziland, P O Luyengo, Swaziland

ABSTRACT

Bambara groundnuts \textit{[Vigna subterranea \{L.\} Verd]} is an important grain legume crop in Swaziland. However, not much has been done to develop agronomic recommendations for its production, hence this experiment on the effects of inter-row spacing on crop growth and seed yield. The experiment consisted of three inter-row spacings. These were 50, 75, and 100 cm between rows at the same plant density, 66,667 plants/ha. The corresponding intra-row spacings were 30, 20 and 15 cm, respectively. One bambara groundnut variety, UNISWA Red was used in a randomised complete block design and the treatments were replicated four times. All plots received 500 kg/ha of a compound fertiliser \([2-3-2 \ (22)]\) before planting. Data collected included seedling emergence, ground cover, sequential growth analysis, agronomic traits using coins for the quantification of preferences, seed yield components and seed yield. The results showed that seedling emergence was highest at the widest inter-row spacing of 100 cm with an intra-row spacing of 15 cm. Ground cover was achieved in the 50-cm and the 75-cm inter-row spacing, but not at the 100-cm inter-row. This would indicate that considerable light was unutilised at the widest inter-row spacing of 100 cm. Leaf length decreased with time after planting and the reverse was true of leaf width. Leaf index also decreased with time after planting. The use of coins, tangible objects of value, for the quantification of tasks/trait such as such earthing up, pod size, pod number and seed yield was user friendly. Seed yield [kg/ha] decreased significantly \([P<0.01]\) with increase in inter-row spacing being 2715, 1485 and 1020 kg/ha for the 50-cm, 75-cm and 100-cm, inter-row spacings, respectively. Nevertheless, there were more green pods in the 50-cm inter-row spacing because of insufficient soil between the rows for earthing up. It was concluded that closer inter-rows had a higher ground cover and might have been more efficient in capturing light and in reducing erosion and suppressing weeds. It is recommended that bambara groundnuts be grown at 50 cm between rows and 30 cm within rows for optimum yield notwithstanding the problem of earthing up. However, farmers with tractor-drawn or ox-drawn equipment are advised to plant in rows 75-100 cm apart at a plant density of about 60,000 to 70,000 plants/ha. Although the counter method of coin for the quantification of tasks/trait was user friendly, it was not useful in the quantification of yield because of the inter-row spacings that obscured and skewed seed yield in favour of wider inter-row spacing.

Key words: Coin method, Ground beans, Intra-row spacing, Jugo beans, Plant density

INTRODUCTION

Bambara groundnut \textit{[Vigna subterranea \{L.\} Verd.],} also known as jugo bean, bambara nut, bambara bean, Congo bean, earth nut ground bean, hog pea nut, hog peanut or \textit{tindlubu} [siSwati], is an indigenous African grain legume crop [Johnson, 1968; Williams, 1993; Azam–Ali et al., 2001]. Sesay \textit{et al.} [1999] and Magagula \textit{et al.} [2002] in their survey about the cultivation of bambara groundnut in Swaziland reported that the crop was very popular in Swaziland and that it had survived generations of cultivation as a subsistence crop among small-scale farmers. They reported that the crop is used both as a food crop as well as a cash crop among farmers throughout the country. In the survey by Sesay
et al. [1999], farm yields were low and over the years, there has been decline in the area under production. However, over 98% of the farmers that they interviewed reported that they, the farmers, would like to see the crop developed with agronomic recommendations for its production so that yields could be increased. Such crops production practices could include inter-row spacing and plant population. Sesay et al. [2003] in their on-farm trials with farmers reported that farmers’ inter-row spacing ranged from 60 to 90 cm and with a wide intra-row spacing ranging from 10 cm to 40 cm, indicating the urgent need for wide production guide in bambara groundnuts to include inter-row and intra-row spacing for maximising crop yields, hence this experiment.

LITERATURE REVIEW

Lack of information for bambara groundnut production in Swaziland
As part of a European Union-funded research project in Swaziland, the research team requested farmers’ assessment of promising bambara lines that were candidates for possible release, following on-station evaluation by farmers’ assessment of promising bambara lines [Edje et al., 2002]. In order to effect this exercise, 20 farmers were each given four promising bambara groundnut lines. In the absence of plant density recommendations for bambara groundnut production, farmers were allowed to plant the entries using inter-row spacing of their choice. Data collected on inter-row spacing used by the farmers showed that space between rows ranged from 60 cm to 90 cm, with 13 [65%] out of the 20 farmers planting at inter-row spacing of 90 cm. only one farmer [5%] out of the 20 farmers planted at 60 cm between rows [Sesay et al., 2003]. The 60-cm inter-row spacing was even wider than the 50-cm that was agreed upon by the regional collaborators in Botswana for all regional trials in the European Union-funded project. This observation would indicate that the 50-cm inter-row spacing that was used for all the regional trials in the European Union-funded project might have been too narrow for a crop that requires considerable amount of soil between rows for earthing up. It was also probable that the genetic potential of the promising varieties would not have been realised given the fact that the inter-row spacing might have been too narrow.

From the above, it is evident that the information on inter-row spacing and plant density is a sine qua non for bambara groundnut production in Swaziland and indeed in other SADC countries [Mkandawire and Sibuga, 2001].

Status of plant density research on bambara groundnut
The manipulation of plant density in order to achieve a balance between crop performance and production factors such as moisture, soil nutrients and “space” has long been recognised as accepted crop husbandry practices [Amon, 1972]. Agronomists have become fully aware that higher potential crop yields made possible by moisture, high soil fertility and high genetic potential of new varieties could only be achieved by using appropriate plant densities [Amon, 1972]. Nevertheless, there is hardly any information on plant population recommendations for bambara groundnut cultivars that are available in Swaziland. Compared to other crops, bambara ground has been a neglected crop until recently [Azam-Ali et al., 2003]. Consequently, very few research data have been published on the response of bambara groundnut to plant density. Even the few available reports have been inconclusive [Sticksel et al., 2002].

Effect of plant density research on the performance of bambara groundnut
Sesay and Yamah [1996] conducted a field experiment on the effects of plant densities ranging from 23,000 to 444,000 plants/ha at an inter-row spacing of 30 cm. Sesay and his colleague reported that they did not achieve the desired plant density, presumably due to plant competition, especially at the higher plant density of 440, 00/ha, and that the highest pod yield was obtained at plant densities ranging between 220,000 and 260,000 plants/ha. Both researchers recommended that bambara groundnuts be planted at 250, 000/ha. This would suggest that farmers could plant at an inter-row spacing of 30 cm and an intra-row spacing of about 13.3 cm. From the results of Edje et al. [2002] as will be seen later, it is probable that earthing up could have been difficult at a narrow inter-row spacing of 30 cm.

Sesay et al. [2003] reported that farmers in Swaziland used inter-row spacing ranging from 60 cm to 90 cm. similar observation was reported by Sticksel et al. [2002], who observed that there was a very wide variation in plant population recommendations for bambara groundnut production in Botswana, Cameroon, Sierra Lone, Togo and Zimbabwe. Sticksel et al.[2002], stated that the lack of plant population densities for bambara groundnut was regrettable, since it had very serious implications for the growth, development and yield of the crop over a range of environments on which the crop is grown.
The observations by Sesay and Yamah [1996] and Sticksel et al. [2002] and the lack of plant density information for bambara groundnut production in Swaziland prompted Edje et al. [2003] to conduct a field trial on the effects of plant density of bambara groundnut yields. In the study, three plant densities were used with only one inter-row spacing of 50 cm. Edje et al. [2003] reported that plant population had no significant effect on seed yield as plants were able to compensate for low plant stand by adjusting for yield with yield components such as number of pods/plant, number of seed/pod and 100-seed mass. Similar results have been reported by Edje et al. [1975] on dry beans [Phaseolus vulgaris], who observed that dry beans exhibited considerable plasticity at low plant densities. However, in the bambara groundnut experiment, leaf number was significantly reduced as plant density increased. Pod quality, as shown by pod shape and colour as well as seed coat colour, was significantly reduced as plant density increased. Edje et al. [2003] attributed the low quality of pods and seeds, as the plant density increased, to insufficient amount of soil available between the row for earthing up. They therefore recommended that wider inter-row row spacings should be investigated along with varying plant densities.

Inter-row and intra-row research on bambara groundnut
Plant density or plant population, the number of plants/ha, can be achieved by manipulation using one plant density while varying both inter- and intra-row spacings and allowing the user of the technology to adopt the inter-row and the intra-row that suit his/her circumstances. The latter, the factorial experiment, is generally preferred as it provides a wider option and addresses both aspects of plant density in one experiment.

Rowland [1993] in his plant density experiment involving both inter-row and intra-row spacing reported that an inter-row spacing of 45 cm and an intra-row spacing of 10-15 cm was optimum for bambara groundnut production. Chui et al. [2003] in their field experiment on the effects of three inter-row spacings of 50, 75 and 100 cm and plant densities of 47,000; and 87,000 plants/ha reported that the highest seed yield was obtained at an inter-row and intra-row spacings of 75 cm and 20 cm, respectively, and at a plant density of 67,000 plants/ha. Chui et al. [2003], however, recommended that other similar experiments be conducted elsewhere to validate their results.

Plant density has two components. These are inter-row and intra-row spacings. For a crop such as bambara groundnut, where earthing up around the base of the crop at full flowering is a recommended practice for highly yield, both optimum inter-row and intra-row spacings are crucial as reported by Edje et al. [2003] and by Balole et al. [2003]. The apparent contradictions in the results of earlier research would be expected because of variation in genotypes used in the studies, abiotic factors such as moisture and soil fertility and biotic factors such as diseases, insect pests and weeds. Nevertheless, there is need for recommendation for inter-row and plant density studies for bambara groundnut production in Swaziland, hence this experiment.

MATERIALS AND METHODS

Experimental site
The experiment was conducted during the 2005/2006 cropping season at Malkerns Research Station. The research station is about 4km from the Faculty of Agriculture, University of Swaziland. Malkerns Research Station is 699 ± 8 m above sea, latitude 26°33.192’S and longitude 31°10.260’E. The site has an annual rainfall of 800-1000 mm; and annual mean temperature ranging from 7.3°C to 26.8°C.

Treatments and experimental design
The experiment consisted of one plant density [66,667 plants/ha]. However, inter-row and intra-row spacings varied as shown in Table 1.

Table 1. Description of treatments used in the experiment.

<table>
<thead>
<tr>
<th>Inter-row spacing [cm]</th>
<th>Intra-row spacing [cm]</th>
<th>Plant density [plants/ha]</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 [Low]</td>
<td>30 [high]</td>
<td>66,667</td>
</tr>
<tr>
<td>75 [Medium]</td>
<td>20 [Medium]</td>
<td>66,667</td>
</tr>
<tr>
<td>100 [High]</td>
<td>15 [Low]</td>
<td>66,667</td>
</tr>
</tbody>
</table>
Plot size
The number of rows per plot varied from 9 to 12 depending on the inter-row spacing. The reason for the varied number of rows/plot was because the differences in the intra-row spacing would give different numbers in a row, yet at each sampling period, equal number of plants were be used. The implication was that at the wider intra-row spacing [for example, 30 cm between the plants], there were fewer plants, and therefore, more rows were used.

Planting and pest control
Planting was done on 8 December 2005, using a landrace, UNISWA Red. UNISWA Red is from Swaziland, dark red in seed coat colour, no eye, has a 100 seed mass of about 50 g. The variety has been described by Sesay et al. [2002]. Inter-row and intra-row spacings were as stated above. Seeds were dusted with Captab, [cis-N- trichloromethylthio-4-cyclohexene1-2 dicarboxide] a fungicide, at the rate of 12 g of commercial product per 10 kg of seed. Prior to planting, Nemacur, a nematicide was applied to all plots at the rate of 10 kg/ha of the commercial product. The nematicide was broadcast and raked into the soil a day before planting. A compound fertiliser, 2-3-2 [22], which also contains 0.5% zinc, was applied at the rate of 500 kg/ha using broadcasting method. This was applied before planting. After broadcasting, the fertiliser was incorporated into the soil with a rake. No other fertiliser was applied during the growth of crop. Cutworms were controlled using cutworm bait, Kombat, by drilling it along the seedling row.

Data collection
The following morphological and physiological traits were collected: seedling emergence, canopy height and width, foliage ground cover, number, length and width of leaflets, flower number, pod number/plant, dry mass of plant parts from sequential growth analysis, days to physiological maturity, number of pods/plant, 100-seed mass and seed yield.

Seedling emergence was when the first true leaf was visible and was recorded on two rows. Canopy height and width were determined weekly using a metre-stake at five random points. Foliage ground cover was determined after the method of Cackett [1964]. Briefly, the method consisted of a frame with two horizontally aligned bars, each one metre long and with 20 holes equally spaced apart. The distance between the two horizontal bars was 20 cm. Foliage cover was determined by passing a metal rod, the size of bicycle spoke, vertically through both vertical holes. If the spoke touched a bambara groundnut leaf in two out of 20 holes, that was regarded as 10% ground cover. Assessment was done randomly at five spots in each plot to obtain foliage cover for each plot. The number of leaves was determined by counting fully expanded three leaflets from four designated plants at weekly intervals. Leaf length and width were determined from the middle leaflet of four fully expanded leaflets. The width was measured across the widest portion of the leaflet. Leaf index was the leaf length divided by the leaf width [Tsukaya, 2002]. Flower count was done daily on eight designated plants and date to full flowering was when all the marked plants had at least one flower per plant. Physiological maturity as when 50% of the sampled plants had pods with seeds showing the characteristic red seed coast of UNISWA Red and the pod wall was beginning to harden. Shelling percentage was seed mass divided by pod mass at harvest [Sesay et al. 2002].

Sequential growth analysis
Sequential growth analysis was done at three-weekly intervals at 21, 42, 63, 84 and 105 days after planting [DAP]. At each harvest, plants were separated into leaves [leaflets and petioles], stems and branches and roots, pods and flowers and nodules. At harvest, the number of pods/plant, seed/pod and 100-seed mass and seed yield were determined. The mass of 100 seeds was determined from one row, 5 m long in order to reduce variation in 100-seed mass sometimes reported for bambara groundnut and other crops. Yield was expressed at 10.0% moisture content.

Quantification of preferences using counter methodology
Ten farmers [five men and five women] were invited to Malkerns Research Station to assess the experiment twice during the season. The first and the second visits were at full flowering of the crop and at harvest maturity, respectively. At each visit, farmers were required to assess the technology using counter methodology with coins for the quantification of their preferences as described by Edje et al. [2002]. Briefly during the exercise, the objective of the experiment was explained to the 10 farmers. They all went over the treatments twice. Thereafter, a farmer was given...
thirty 50-cent coins for the quantification of their preferences. In effect, farmers were asked how many of the 30 coins they were willing to spend on the technology being evaluated. How much was the technology worth to them? Thereafter, each farmer was allowed to assess the said technology with one at a time in order to avoid farmers conferring among themselves. Only one technology was assessed at a time. The number of coins for each assessment were collected and counted before the next farmer was invited. If in the unlikely event that a coin was missing it was quietly replaced by the researcher. The data were analysed statistically using MSTAT C with the farmers as replicates. At the end of the entire assessment, the farmers were reassembled and discussed the results over refreshment.

Data analysis
Data were analysed using MSTAT-C statistical Program, version 1.3 [Nissen, 1983] Michigan State University, East Lansing, Michigan. Means were separated using the least significance [LSD] test.

RESULTS AND DISCUSSION

Soil temperature
Data on soil temperature taking at 104 DAP are shown on Table 2. Inter-row spacing had no significant effect on soil temperature. Surprisingly, soil temperature increased with depth [0 5, 10 and 15 cm]. Factors contributing to increase in heat budget with time might have accounted for the observed phenomenon. Soil temperature data could have been taken over a longer period of time for more meaningful interpretation of effects of inter-row spacing on soil temperature.

Table 2. Soil temperature at the experimental site at four depths

<table>
<thead>
<tr>
<th>Inter-row spacing [cm]</th>
<th>Depth [cm]</th>
<th>0 [Surface]</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>20.8</td>
<td>20.5</td>
<td>23.0</td>
<td>22.5</td>
<td>21.7</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>20.8</td>
<td>20.8</td>
<td>23.0</td>
<td>22.3</td>
<td>21.7</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>20.8</td>
<td>20.5</td>
<td>22.5</td>
<td>22.8</td>
<td>21.7</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>20.3</td>
<td>20.6</td>
<td>22.8</td>
<td>22.5</td>
<td>21.6</td>
<td></td>
</tr>
<tr>
<td>S.E. ±</td>
<td>0.29</td>
<td>0.34</td>
<td>0.47</td>
<td>0.34</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Seedling emergence
Seedling emergence was much more rapid at the 100 cm inter-row spacing [15 cm intra-row spacing] than at the other two inter-row spacing [Figure 1]. It is possible that at the narrower intra-row spacing [wider intra-row], *mutual assistance from seedling vigour from neighbouring plants might have been responsible for the observed phenomenon [Edje et al., 2002].
Ground cover [%]
The modified Cackett’s canopy measuring device for the determination of canopy ground cover was used. Data on ground cover within inter-row spacing increased with days after plating [Figure 2]. Generally, the ground cover was lower in the inter-row spacing (5cm) than at the wider (100 cm) inter-row spacing. Similar results were reported by Edje et al [2002]. While weed assessment was not done in the trial, the fast canopy closure would be expected to reduce weed population, reduce soil and water loss and increase the capture of light for photosynthesis. This may explain the reason for advocating solid planting of some legume crops such as soybean [Glycine max]. As would be expected, the closure of intra-row spacing was much faster in the plants spaced at 15 cm between rows than those spacing at 30 cm between rows [Figure 2]. By 78 DAP; canopy closure was complete within rows in all treatments.

Figure 1. Seedling emergence of bambara groundnut at three inter-row spacing at 11 sampling periods.

Figure 2. Ground cover [%] of bambara groundnut at three inter-row spacing at 17 sampling periods.
Canopy height and width
Canopy height, an index of plant height [not shown], increased within days after planting. Canopy height was generally higher at the low inter-row spacing than at the high inter-row spacing. Similar results were reported by Edje et al. [2003].

Data on canopy width, an index of the spread of the plant to cover the inter-row spacing [not shown], revealed that there was complete canopy cover at 55 DAP at the low inter-row spacing. Complete ground cover, as determined by canopy width, was not achieved at the high inter-row spacing during the experiment. This could have implication for light, weed management, soil and water erosion and soil temperature. The correlation coefficient between ground cover between rows and canopy width was weak \(r = 0.209\).

Leaf number/plant, leaf index and crude leaf area
Data on leaf number, leaf index and crude leaf area are presented in Figures 3, 4 and 5. Initially, there was no consistent pattern in the number of leaves/plant [Figure 3]. But increased after 127 DAP [Figure 5]. There was no significant difference among the treatments with respect to the number of leaves/plant.

Leaf index [leaf length divided by leaf width] decreased with days after harvest because leaf length decreased with time while leaf width increased with time [Figure 4]. Edje et al. [2003] reported that leaf index in bambara groundnut decreased with day after planting.

The crude leaf area [the product of leaf length and leaf width] showed that there was an increase in leaf area with time. This would indicate that there was a compensation for leaf length by increase in leaf length [Figure 5].

![Figure 3. Number of leaves/plant of bambara groundnut at three inter-row spacing at six sampling periods.](image-url)
Flower production
Treatments had no significant effect on the number of flower produced/plant. It was generally higher with increase in inter-row spacing and ranged from 19.3 to 31.8 flowers/plant at 61 DAP for the low and the high inter-row spacings, respectively [Figure 6]. The highest number of flowers/plant was 50 and this was at the 100-cm inter-row spacing at 63 DAP. Peak flowering was at 63 DAP for all treatments. Thereafter, there was a decline, presumably because of onset of pod formation. Edje et al. [2003] reported increase in cumulative number of flowers/plant up to 91 DAP. The apparent reduction in the number of flowers/plant reported in the present experiment may be explained on the basis of the fact that the data show the number of flowers counted on the indicated date and not the cumulative number of flowers.
Figure 6. Number of flowers/plant of bambara groundnut at three inter-row spacing at 11 sampling periods.

**Total number of pods/plant, pod dry mass and total dry mass [g/plant]**

The number of pods/plant, pod dry mass [g] and the total dry mass above ground [g/plant] are presented in Figures 7, 8 and 9. Treatments significantly [P <0.1] affected the dry mass of pods/plants [Figure 7]. The dry mass of pods/plant increased from 90 DAP and declined after 117 DAP [Figure 8]. The number of pods/plant ranged from 44.0 to 53.0 for the low and the high inter-row spacings, respectively [Figure 9]. However, there was no significant difference among treatments.

Figure 7. Number of pods/plant of bambara groundnut at three inter-row spacing at two sampling periods
Quantifications of preferences using counter methodology

Ten assessors [five male and five female] were invited to assess various characteristics/traits on the effects of the inter-row spacing on crop management and yield using coins, objects with quantifiable values using the method after Edje et al. [2002]. The ease of earthing up was significantly \( P < 0.05 \) affected by treatments [Table 3]. The number of coins for 50 cm, 75 cm and 100 cm were 1.6, 3.9 and 4.0, respectively. At the high inter-row spacing [100 cm], there was more soil for earthing up than at the low inter-row spacing [50 cm]. However, the reverse was true for ground cover, where the 100-cm inter-row spacing had the least number of coins [2.4 compared to 4.0 for the 50-cm inter-row spacing [Table 3]. There were differences among treatments in ground cover.

The assessment of preferences for the pod size and the number of pods/plant followed similar trend, being lowest at the 50-cm inter-row spacing and highest at the high inter-row spacing. Seed yield was also assessed visually and was
based on the volume of seeds in the tray into which harvested pods were placed. Inter-row spacing had effect on seed yield with the 50-cm, 75-cm and the 100-cm spacing receiving 2.0, 2.7 and 3.5 coins, respectively. The correlation of determination was $R^2 = 0.9985$, indicating that the differences in inter-row spacing could have accounted for 99.9% of differences in pod yield/row. It should be noted that in harvesting the pods, equal row lengths were used. There was no regard to area for each plot from which the pods were harvested. For example, while all the rows were 5 m long, the area of each plot was 2.5$m^2$, 3.75$m^2$ and 5.0$m^2$, respectively for the 50-cm, 75-cm and the 100-cm inter-row spacing. The difference in area was not factored into the visual assessment. As will be seen later, the yield, determined on an area basis was the reverse of the yield based on metre row length.

Table 3. Number of coins for earthening up, ground cover, pod size, pods/plant and seed yield

<table>
<thead>
<tr>
<th>Inter-row spacing [cm]</th>
<th>For earthening</th>
<th>Ground cover</th>
<th>Pod size</th>
<th>Pods/plant</th>
<th>Pod yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>1.6</td>
<td>4.0</td>
<td>1.7</td>
<td>2.3</td>
<td>2.0</td>
</tr>
<tr>
<td>75</td>
<td>3.9</td>
<td>3.3</td>
<td>2.2</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>100</td>
<td>4.0</td>
<td>2.4</td>
<td>4.0</td>
<td>4.4</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Seed yield components and seed yield

Data for pod mass [g/plant], seed mass [g/plant], shelling per cent and 100-seed mass [g] are presented in Table 4. Inter-row spacing had no consistent pattern in all the above parameters, nor was there any significant difference among treatments. Nevertheless, the mass of 100 seeds at the 50-cm inter-row spacing was 4.9% higher than the two other inter-row spacing.

Seed yield [kg/ha] decreased significantly [P < 0.01] with increase in inter-row spacing [Figure 10]. The coefficient of determination was $R^2 = 0.8252$, indicating that 82.52% of the reduction in seed yield might have been due to increase in inter-row spacing. This was contrary to what was observed when yield was assessed visually based on row length and not on area.

Although the highest yield was at the 50-cm spacing, there were also more green pods. This was presumably due to insufficient soil to cover the pods during earthing up. Similar results were reported by Edje et al. [2003]

Table 4. Pod mass [g/plant], seed mass [g/plant], shelling per cent and 100-seed mass [g]

<table>
<thead>
<tr>
<th>Inter-row spacing [cm]</th>
<th>Pod mass [g/plant]</th>
<th>Seed mass [g/plant]</th>
<th>Shelling per cent</th>
<th>100-seed mass [g]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>22.9</td>
<td>16.2</td>
<td>70.1</td>
<td>55.2</td>
</tr>
<tr>
<td>75</td>
<td>28.8</td>
<td>21.1</td>
<td>73.5</td>
<td>52.6</td>
</tr>
<tr>
<td>100</td>
<td>25.3</td>
<td>17.3</td>
<td>68.7</td>
<td>52.6</td>
</tr>
<tr>
<td>Mean</td>
<td>25.6</td>
<td>18.2</td>
<td>70.8</td>
<td>53.9</td>
</tr>
<tr>
<td>S.E. +</td>
<td>4.7</td>
<td>2.6</td>
<td>5.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>
CONCLUSION

Seedling emergence was highest at the inter-row spacing of 100-cm, where the intra-row spacing was 15 cm. Mutually assistance from neighbouring seedlings, that were close at the 15-cm intra-row spacing might have accounted for the rapid rate of emergence. Complete ground cover was not achieved at the widest inter-row spacing of 100 cm throughout the experiment. Farmers admitted that the use of coins for the elicitation of preferences fun and easier to use than the ordinal, Likkert scale or the use of questionnaires. Seed yields at the 50-, 75- and 100-cm inter-row spacings were 2715, 1485 and 1020 kg/ha

RECOMMENDATION

The following recommendations emerge from the experiment:
[1]. Bambara groundnut should be planted at 50 cm between rows and at 30 cm within rows for optimum yield, notwithstanding the difficulty from problem of earthing up. However, where farmers have access to oxen or tractor for earthing up, 75-cm inter-row is recommended provided the plant density is about 60, 000 to 70, 000 plants/ha
[2] The use of coins, tangible objects with quantifiable value was very user friendly and entertaining. But was not useful for the quantification of yield because of the differences in inter-row spacing that obscured and skewed the yield in favour of the wider inter-row spacing, ignoring the aspect of area.
LITERATURE CITED

Central Statistics Office, Mbabane.


Gaborone, Botswana 8-12 August 2003.

[2001]. Assessing the potential of an underutilized crop: A case study using Bambara groundnut. Experimental
Agriculture 37:433-472.

International Bambara Groundnut Symposium. Botswana College of Agriculture, Gaborone, Botswana. 8-12 August
2003.

and response to row spacing and population density. Proceedings of the International Bambara Groundnut

Cackett, K. E. [1964]. A simple device of measuring canopy cover. Rhodesian Journal of Agriculture Research 2: 56-
62.

CIAT. [1987]. Standard system for the evaluation of bean germplasm. Centro Internacional de Agricultura Tropical
Cali, Colombia.

to plant density. Proceedings of the International Bambara Groundnut Symposium. Botswana College of Agriculture,
Gaborone, Botswana. 8-12 August 2003.

Edje O. T., Sesay, A. and Magagula, C. N. [2002]. Evaluation of Bambara groundnut landraces by farmers in
Swaziland. In: Sesay, A., Edje, O. T. and Cornelissen, R. [Eds.]. Proceedings of mid-season workshop on
increasing the productivity of bambara groundnut [Vigna subterranea [L.] Verdc.] for sustainable food

Edje, O. [2001]. Technology development and transfer: Use of coin method in assessment of technology by farmers.
Proceedings of workshop on Capacity building and collaboration: The key to sustainable agricultural management and
development. Mphopoma Training Centre, June 18-20, 2001, Malkerns, Swaziland.

and plant population. Turrialba 25: 79-84.


Magagula, C.N. Sesay, A., Edje, O.T., Nkosi, B.S., Mamba, Z., Mabuza, K. and Dlamini, T. [2002]. Farmer and
consumer preferences for bambara groundnut ideotype in Swaziland. In: Sesay, A., Edje, O. T. and Cornelissen, R.
[Eds]. Proceeding of mid-season workshop on increasing the productivity of bambara groundnut [Vigna subterranea
[L] Verdc.] for sustainable food production in semi-arid Africa. University of Swaziland, Kwaluseni, Swaziland. August

Niseen, O. [1983]. MSTAT-C: A microcomputer program for the design, management, and analysis of agronomic research experiments. Michigan State University, East Lansing, Michigan, USA.


