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Original Research Article

The growth and development of two pearl millet landraces as affected by intra-row spacing

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A B S T R A C T

Two field experiments were conducted on two pearl millet landraces (Serere 6A and Tswana) during the 2009/2010 growing season at Botswana College of Agriculture (BCA), which is located in Sebele. This was to evaluate the response of the two landraces to different intra-row spacing in Botswana. The treatments consisted of three intra-row spacing of 15, 25 and 35 cm with a constant row spacing of 75 cm, each replicated four times in a randomized complete block design (RCBD). Growth and development parameters monitored were as follows; plant height, leaf area, number of leaves, number of tillers measured on weekly basis whereas, total dry matter was measured once at termination. Results of the study showed a non-significant ($p>0.05$) treatment effect on plant height of the two landraces in all weeks except for Serere 6A on week 9, where a significant ($p<0.05$) treatment effect was observed for wider plant spacing (35 × 75 cm). Wider plant spacing revealed superior absolute numbers as compared to the narrower plant spacing. Leaf area of the two pearl millet landraces was significantly higher in the wider plant spacing (35 × 75 cm) compared to the narrower spacing. Leaf numbers significantly increased ($p<0.05$) in the wider plant spacing at week 5 and week 11 for Serere 6A. A non-significant treatment effect was revealed for Tswana millet in all weeks and a similar trend was observed for number of tillers. Both landraces produced the highest total dry matter which was significantly ($p<0.01$) higher at the widest plant spacing (35 × 75 cm) compared to the narrower plant spacing. Based on the findings wider plant spacing outperformed the narrower plant spacing for all the measured growth and development parameters.

Keywords

Plant spacing, pearl millet landraces, growth and development parameters

Introduction

Pearl millet (*Pennisetum glaucum* (L). R. Br) is a crop grown in the semi-arid and dry lands of Africa and Southeast Asia (Baltensperger, 2002). The world's area planted to millet is about sixty five million hectares, with the major part in India and Africa (Nene and Singh, 1975). Pearl millet is the world's sixth most important cereal crop in the world after wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays* L.), barley (*Hordeum vulgare*) and sorghum (*Sorghum bicolor*) (Henry and Kettlewell, 1996; Singh et al., 2003). It is a short-day crop that flowers, or flowers earlier, when day lengths are short (Billiard and Pernes, 1985; Clerget et al., 2007) and long photoperiod delays floral initiation (Uzoma et al., 2010). Pearl millet grain is the staple diet for rural households in the world's poorest countries (Basavaraj et al., 2010) and provides food to about five hundred million people in the arid and semi-arid tropics particularly in Southeast Asia (Yayock et al., 1988; National Research Council (NRC), 1996). Pearl millet stover is a valuable livestock feed in India and Africa (Basavaraj et al., 2010). In countries like the United States of America pearl millet is grown as a summer forage crop, seed for the bird feed industry and wildlife (Obeng et al., 2012).

Pearl millet is the most drought tolerant warm-season cereal crop predominantly grown as a staple food grain and source of feed and fodder (Sathya et al., 2013) and is one of the most reliable cereal crops grown in rain fed regions of the arid and semi-arid tropics (Uzom et al., 2010). Infact it is the only suitable and efficient crop for arid and semiarid conditions because of its efficient utilization of soil moisture and higher level of heat tolerance than sorghum and maize (Shah et al., 2012). Because of its tolerance, it can be grown in areas where other cereal crops such as maize and wheat would not survive (Basavaraj et al., 2010) and can yield in areas that receive rainfall as low as 200 to 250 mm (Bidinger and Hash, 2003).

Pearl millet is well adapted to areas characterised by poor soils (Ntare, 1990; Hajor et al., 1996), frequent drought, high temperatures and many pests and diseases (Ntare, 1990). However, it can produce grain yields below 500 kg ha^{-1} because of low soil fertility, drought, and poor or inadequate management systems (Krogh, 1997; Buerkert et al., 2002; Gandah et al., 2003). In arid and semi-arid tropics farmers maintain soil fertility by fallowing and the application of livestock animal manure is the main soil fertility supplement (Shapiro et al., 1993; Esse et al., 2001) because of high costs associated with chemical fertilisers. Grain yields of pearl millet can be reliably high when chemical fertilisers are applied to soils with sufficient moisture (Burton et al., 1972; Menezes et al., 1997; Maman et al., 2000; Diseko, 2005).

Pearl millet production is concentrated in the developing countries which account for over 95% of the production and acreage (Basavaraj et al., 2010). The area sown to the crop in Eastern and Southern Africa is estimated at 2 million hectares. In Botswana the areas cultivated to pearl millet gradually decreased from 16 000 to 13 000 hectares in 2011 (Statistics Botswana, 2013). In the 1980s, the total annual millet production was 3700 metric tonnes with an average yield of 285 kg ha^{-1} (Ministry of Agriculture (MOA), 1988). Although millet is still an important crop to Botswana, the yield fell to 2511 metric tonnes in 2011 and the average yield also decreased to 189 kg ha^{-1} (Statistics Botswana, 2013). Low and erratic rainfall leading to drought period of varying lengths, poor soil fertility, low or zero application of fertilizers, and low water holding capacity, traditional practices such as broadcasting are probably among the factors affecting millet production.

Plant spacing plays an important role on growth, development and yield of cereal crops. Optimum plant density ensures that plants grow properly with their aerial and underground parts by utilizing more sunlight and soil nutrients (Miah et al., 1990). Closer spacing hampers intercultural operations and in a densely populated crop, the inter-plant competition for nutrients, air and light is very high, which usually results in mutual shading, lodging and thus favours more straw yield than grain yield (Bhowmik et al., 2012). Vegetative development in pearl millet is much influenced by the availability of moisture (Mahalakshmi et al.,1987) soil fertility and the planting density (Azam-Ali et al.,1984; Carberry et al.,1985). Plant population density is a management variable that affects the production and quality of most crops (Shaw et al., 2008). Though optimal plant densities for pearl millet production differ among geographic regions, research indicates that grain yield generally increases as plant density increases (Jones and Johnson, 1991; M'Khaitir and Vanderlip, 1992; Heiniger et al., 1997). Crop potential yield may also be affected by intra-row spacing (Jones and Johnson, 1991; Limon-Ortega et al., 1998; Staggenborg et al., 1999). It has been reported that effects of plant population are not easily disentangled from within-row spacing differences (Obi, 1991; Pande and Kurunakar, 1992; Willocquet et al., 2000; Snider et al., 2002). The objective of this study was to evaluate the effect of intra-row spacing on the growth and development of two pearl millet landraces.

Materials and Methods

The study site

The field experiments was conducted on two pearl millet landraces (Serere 6A and Tswana) at the Botswana College of Agriculture (BCA) in Sebele, Gaborone (latitude: of 24°33'S, longitude: 25°54'E, elevation: 994 m above sea level) during the 2009/2010 growing season. The climate of the study area is semi-arid with an average annual rainfall (30 year mean) of 538 mm (Bekker and De Wit, 1991; Legwaila et al., 2012). Most of rainfall is received in the summer months, starting in late October, continuing to March/April. Soils are predominantly sandy loams (76% sand, 10% silt and 14% clay) with low water holding capacity, low cation exchange capacity (1.2 meq/100g) and pH of 6.3.

Experimental design

The experiments were laid out in a randomized complete block designs (RCBD) with three intra row spacing of 15 cm, 25 cm and 35 cm being treatments 1-3 respectively. The inter row spacing was kept constant at 75 cm. Each treatment was replicated four times (Figure 1).

Field preparation

The experiments were established on piece of land previously ploughed using a tractor. The land was leveled using hand tools to provide a medium fine tilth for the growth of the crops. Measuring and marking of hills was done thereafter. After planting, the field was watered to field capacity. The study was rainfed; however, in the absence of rain watering was done to keep the soil moist. Weeds were removed by hand hoeing or uprooted as they appeared in the experimental unit. Insect pests were hand-picked and physically destroyed.

Performance indicators

The following parameters were monitored; plant height, leaf area, number of leaves, number of tillers on weekly basis whereas, total dry matter was measured once at termination. Planting/sowing was done on the 16th January 2010 and the study lasted for eleven weeks. Plant height was measured using a measuring tape from the base to the terminal leaf. Ten plants were randomly selected from each replication and tagged. Ten fully expanded leaves were randomly sampled from the tagged plants and the area was measured by tracing the leaf on A1 graph pad with grid squares, each measuring 1 × 1 cm. Number of leaves and tillers were determined quantitatively by counting immediately after true leaves had fully grown or expanded. At termination of the trial, all the tagged plants were harvested and the roots dug out from each replicate and placed into brown weighing paper bags and taken to the Department of Crop Science and Production, BCA, laboratory. The roots were placed in a 2 mm mesh sieve and gently washed in a big tub filled with water; the soil free roots were collected and dried off using a tissue paper prior to drying. The samples were oven dried to constant weight at 80°C using a hot air oven (Scientific Series 2000). Weight was measured using an electronic balance (PGW 4502e).

Data analysis

The data was subjected to analysis of variance (ANOVA) using the STATISTIX-8 program. Where a significant F-test was observed and means comparison tests were carried out using Least Significant Difference (LSD) at $p \leq 0.05$ to separate treatment means.

Results and Discussion

Plant height

Plant height is an important component which helps in the determination of growth (Murányi and Pepó, 2013). Overall results in Table 1 showed that there were no significant differences in plant height among spacings of the two millet landraces for the period of evaluation. However, the widest spacing for Serere 6A revealed significantly ($p<0.05$) taller plants than the narrower spacing in week 9 of the study probably because the inter row spacings were too wide (75 cm). The wider plant spacing produced superior absolute plant height compared to the narrower spacing which is supported by results of studies conducted elsewhere (Kaushik and Gautam, 1984; Jimba and Adedeji, 2003; Zarafi and Emechebe 2006; Maas et al., 2007; Ahmed et al., 2010; Kumar et al., 2013). In contrast, Shinggu and Gain (2002) reported that a narrow intra-row spacing of 10 cm produced taller finger millet plants than 20 cm intra-row spacing.

Leaf area

The results in Table 2 showed a highly significant difference ($p<0.01$) in leaf area between the three spacing for Serere 6A between week 5 and 7. From week 9 to the end of the study, plants in the wider spacing had a significantly ($p<0.05$) higher leaf area than the two narrower spacing. The leaf area of the Tswana landrace differed significantly ($p<0.01$) between the three spacing (Table 2). The present results showed that the wider spacing (35 × 75 cm) had the largest leaf area compared to the narrower spacing throughout the duration of this study. This is in agreement with results of a study conducted elsewhere which reported the largest leaf area of a rainfed pearl millet planted at 90 cm than 50 cm spacing (Kamal et al., 2013).

The narrow spacing in the present study produced thin plants with decreased leaf area probably due to competition between crowded plants for light, water and nutrients (Carberry and Campbell, 1985; Ayub et al., 2007). Ideally, plants spaced equidistantly from each other compete minimally for nutrients, light and other growth factors.

Leaf numbers

Results in Table 3 showed that plant spacing had no effect in leaf numbers except in week 5 and 11 when the narrow spaced Serere 6A plants displayed significantly lower ($p<0.05$) number of leaves than their widely spaced counterparts. In week 11 the widely spaced Serere 6A plants had a significant more number of leaves than the other two spacing. It is worth noting that the number of leaves in the two Serere 6A wider spacing was always slightly higher than in the 15 × 75 cm spacing. The results also show that plant spacing had no significant effect on the number of leaves for the Tswana landrace which is in agreement with Kamal et al. (2013). Although there was no significance difference, it is possible that the closely spaced plants grew taller plants with slightly few leaves probably due to competition. Babaji et al. (2012) conducted a study on maize and observed no significant difference in leaf production in plants spaced at 25 cmand their counterparts spaced at 50 cm. Likewise, the difference in leaf production between maize spaced at 50 cm was not significantly different from those spaced at 75 cm. Lylocks et al. (2013) reported that number of leaves per plant and leaf area per plant were not statistically different in a maize/ginger intercrop at different intra-row spacing.

Tiller numbers

There are three types of tillering in pearl millet (synchronous, non-synchronous basal tillering and sub-terminal tillering) (Andrews et al., 1975). According to Obeng et al. (2012) in sub-tillering, the tillers arise from the auxiliary buds, whereas in the synchronous and non-synchronous tillering, tillers arise from the basal of the leaf buds. De Datta (1981) reported that the number of tillers and panicles per square meter in a rice population are largely a function of planting density or seed rate and grain yield. The number of tillers for Serere 6A were significantly ($p<0.05$) affected by spacing in week 5 and 11 with the wider spacing increasing them (Table 4). Plants grown in the wider spacing had a slightly higher number of tillers. This shows that individual plants fare better at wider spacing (Jimba and Adedeji, 2012). The Tswana landrace showed a significant ($p<0.05$) plant spacing treatment effect in week 7. Plant spacing had no effect on number of tillers produced in other weeks. Gaya and Daraja (2013) reported no significant differences in the number of tillers produced due to intra-row spacing in millet. Contrary to our results, Diseko (2006) observed the lowest number of tillers at spacing of 10 × 20 cm and the highest number of tillers at 20 × 20 cm spacing.

Total dry matter

There was a significant ($p<0.01$) differences in dry matter among the spacings in the two pearl millet landraces (Table 5). The wider spacing had higher dry matter yield than the close spacing and this in agreement with the findings by Jimba and Adedeji (2003). Prior studies on maize conducted elsewhere also reported reduced dry matter in closely spaced plants (Steiner, 1984; Makinde and Alabi, 2002; Ibeawuchi et al., 2008; Moosavi et al., 2012) probably due to competition for resources which was evident in this study. Contrary to results of this study dry matter was found to be significantly higher at closer than wider spacing in sorghum (Stickler and Laude, 1960; Steiner, 1986; Sneider et al., 2008), soybean (De Bruin and Pederson, 2008) and maize (Cox et al., 2006). As spacing influenced dry matter production but had no effect on pearl millet plant height, it is suggested that wider plant spacing enhanced better plant vigour. This is supported by the report of Jimba and Adedeji (2003) where wider spacing in Vetiver grass *(Vetiveria zizanioides* L.*)* enhanced plant vigour.

Figure.1 Experimental sketch map (same for each landrace)

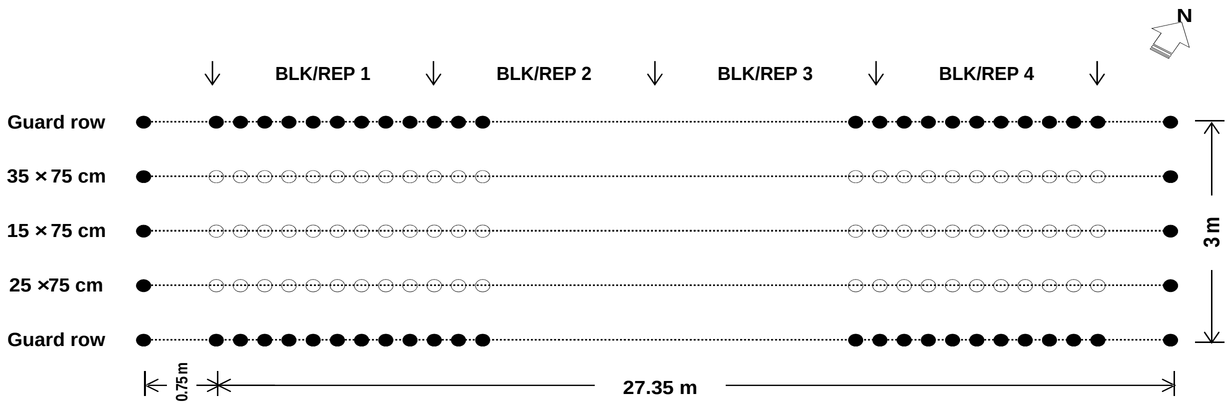

Table.1 Performance of two millet cultivars on plant height (cm) as influenced by plant spacing

Plant spacing	Serere				Tswana			
	Week 5	Week 7	Week 9	Week 11	Week 5	Week 7	Week 9	Week 11
15 × 75 cm	47.3	140.0	150.0^{b}	167.0	47.5	150.0	153.0	164.0
25 × 75 cm	49.3	152.0	164.0^{ab}	172.0	48.0	150.0	156.0	161.3
35 × 75 cm	50.5	157.0	176.0^{a}	182.0	49.0	159.3	165.0	171.0
Significance	ns	ns	*	ns	ns	ns	ns	ns
LSD 0.05	ns	ns	14.09	ns	ns	ns	ns	ns
CV (%)	8.5	7.24	5.27	7.86	13.40	16.28	15.89	15.15

* Significant at $p<0.05$, ns non-significant at $p>0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different

Table.2 Performance of two millet cultivars on leaf area (cm^2) as influenced by plant spacing

Plant spacing	Serere				Tswana			
	Week 5	Week 7	Week 9	Week 11	Week 5	Week 7	Week 9	Week 11
15 × 75 cm	114.0^{c}	127.0^{c}	154.0^{b}	156.8^{b}	95.5^{c}	137.0^{c}	145.8^{c}	158.0^{c}
25 × 75 cm	154.0^{b}	166.0^{b}	172.0^{b}	180.0^{b}	157.0^{b}	171.0^{b}	179.0^{b}	194.0^{b}
35 × 75 cm	198.0^{a}	215.0^{a}	227.0^{a}	243.0^{a}	212.0^{a}	232.0^{a}	244.0^{a}	272.0^{a}
Significance	**	**	*	**	**	**	**	**
LSD 0.05	24.35	15.44	40.13	37.47	23.88	31.62	27.21	31.33
CV (%)	9.06	5.27	12.58	11.20	8.92	10.15	8.30	8.70

** Highly significant at $p<0.01$, * significant at $p<0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different

Table.3 Performance of two millet cultivars on number of leaves as influenced by plant spacing

Plant spacing	Serere				Tswana			
	Week 5	Week 7	Week 9	Week 11	Week 5	Week 7	Week 9	Week 11
15 × 75 cm	5.3[b]	6.0	7.0	7.0[b]	5.0	5.0	7.0	7.0
25 × 75 cm	7.0[a]	7.0	8.0	8.0[ab]	5.0	6.0	7.3	7.3
35 × 75 cm	7.0[a]	8.3	8.0	9.0[a]	6.0	6.0	7.8	7.8
Significance	*	ns	ns	*	ns	ns	ns	ns
LSD 0.05	1.12	ns	ns	1.15	ns	ns	ns	ns
CV (%)	10.06	18.07	16.27	8.33	17.68	20.38	18.32	15.25

* Significant at $p<0.05$,ns non-significant at $p>0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different

Table.4 Performance of two millet cultivars on number of tillers as influenced by plant spacing

Plant spacing	Serere				Tswana			
	Week 5	Week 7	Week 9	Week 11	Week 5	Week 7	Week 9	Week 11
15 × 75 cm	2.0[b]	3.5	4.0	4.0[b]	3.0	4.0[b]	4.0	4.0
25 × 75 cm	4.0[a]	4.0	5.0	6.0[ab]	3.0	3.0[b]	4.0	5.0
35 × 75 cm	4.0[a]	4.0	6.0	8.0[a]	4.0	5.0[a]	6.0	6.0
Significance	*	ns	ns	*	ns	*	ns	ns
LSD 0.05	1.41	ns	ns	2.94	ns	1.15	ns	ns
CV (%)	24.49	19.44	26.67	28.33	28.28	16.67	31.94	26.67

* Significant at $p<0.05$, ns non-significant at $p>0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different

Table.5 Performance of two millet cultivars on total dry matter (leaf, stem and root) as influenced by plant spacing

Plant spacing	Serere	Tswana
	Total dry matter	Total dry matter
15 × 75 cm	78.48c	78.79c
25 × 75 cm	103.65b	104.65b
35 × 75 cm	125.22a	117.45a
Significance	**	**
LSD 0.05	15.10	8.51
CV (%)	8.52	4.91

** Highly significant at $p<0.01$, * significant at $p<0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different

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