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Effect of plant densities and cropping systems on yield components of cowpea (*Vigna unguiculata* L. Walp.) genotypes and sorghum (*Sorghum bicolor* L. Moench.)

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Abstract

A field experiment involving two plant densities (83,333 and 166,666 plants·ha^{-1}) and two cropping systems (sole crop and intercropping) was conducted for two years (2005 and 2006) at Nietvoorbij, Stellenbosch, South Africa, to evaluate three local ('Bensogla', 'Sanzie', and 'Omondaw') and two improved cowpea genotypes (ITH98-46 and TVu1509) grown in association with sorghum. High plant density and intercropping significantly decreased cowpea and sorghum yields. Performance of cowpea genotypes, however, varied significantly. Overall grain yields were highest for 'Sanzie'. Shelling percentage, 100-seed weight, and seed yield were generally higher for the farmer-selected local cultivars compared with the improved varieties, although the number of pods·plant^{-1} followed a reverse trend. Sorghum intercropped with TVu1509 gave the highest seed yield. Negative effects of higher plant population density on number of seeds·pod^{-1} and 100-seed weight were manifested only under sole crop situations. Regardless of plant density and genotypes, combined productivity of cowpea and sorghum increased in the intercropped plots as exemplified by higher land equivalent ratios (LER_T; 1.29 to 1.61). Highest LER_T value was observed in the 'Omondaw'+sorghum mixed culture.

Keywords: Intercropping, Plant population density, Land equivalent ratio.

Introduction

Cowpea (*Vigna unguiculata* L. Walp.) is a valuable crop used by the resource poor farmers in Africa (Ayisi et al., 2000). Its tolerance to moisture stress (Nkongolo, 2003) along with numerous other advantages ranging from nutritional, soil fertility improvement, and weed control (Aliyu and Emechebe, 2006), make it a useful component of the cropping systems involving cereals such as sorghum (Blade et al., 1992). Grain yields of cowpea and sorghum in Africa, however, have been reported to be dependent on plant population density, cropping systems, and cultivars (Hegstad et al., 1999). Furthermore, cowpea yields have been low, typically ranging between 0.1 to 0.4 Mg·ha^{-1} in the traditional systems compared to ~3.0 Mg·ha^{-1} in experimental plots (Sivakumar et al., 1996). Inappropriate planting geometry as practiced by most African farmers, leading to competition for site resources, is the principal reason for the low productivity (Hauggaard-Nielsen et al., 2006). However, cowpea genotypes grown in association with cereals adopting planting patterns that optimize complementary interactions may improve land use efficiency (Hauggaard-Nielsen et al., 2001) and land equivalent ratio (Jahansooz et al., 2007). Asafu-Agyei et al. (1997) showed that planting arrangement of two rows of cowpea after every two rows of maize (*Zea mays* L.) gave greater grain yields for both crop components and greater land equivalent ratio than a one-to-one row system. Although considerable knowledge has been accumulated on mixed culture system using different cereal components (Reddy et al.,

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1992), data on the effect of plant density and cropping systems on yield components of different cowpea genotypes grown with or without sorghum are inadequate in the African context. This study was, therefore, designed to assess the effect of plant population density on yield components of five cowpea genotypes grown either as sole crop or intercropped with sorghum.

Materials and Methods

The study was conducted at the Agricultural Research Council (ARC) Nietvoorbij station in Stellenbosch, South Africa (33º542 S, 18º142 E, and 146 m altitude), during the summer of 2005 and 2006. The area receives a mean annual rainfall of 713 mm and has mean annual day and night temperatures of 22.6ºC and 11.6ºC respectively, with a mean monthly solar radiation of 544 MJ $m^{-2} \cdot m^{-1}$. The mean annual potential evapotranspiration (ET_0) as measured by Penman Monteith (Monteith, 1965) was 1,573 mm. The soil is a sandy loam classified as Glenrosa, Hutton form (SCWG, 1991), equivalent to skeletic leptosol in the FAO soil classification system. Prior to planting each year, soil samples (0 to 20 cm soil depth) were collected from the experimental plots, pooled, and sub-samples taken for chemical analysis. The soil physico-chemical properties were as follows: pH ($CaCl_2$) = 6.2±0.03, P = 18.7±1.8 $mg \cdot kg^{-1}$, K = 137.2±4.8 $mg \cdot kg^{-1}$, Ca = 69.6±1.8 $mg \cdot kg^{-1}$, Mg = 16.1±0.5 $mg \cdot kg^{-1}$; Na = 90.5±2.3 $mg \cdot kg^{-1}$, S = 4.1±0.2 $mg \cdot kg^{-1}$, Fe = 254.7±9.7 $mg \cdot kg^{-1}$, Cu = 3.65±0.1 $mg \cdot kg^{-1}$; Zn = 3.3±0.2 $mg \cdot kg^{-1}$, Mn =8.7±0.3 $mg \cdot kg^{-1}$, and B = 0.4±0.0 $mg \cdot kg^{-1}$. The experimental sites had a previous history of table grape (*Vitis vinifera* L.) cultivation with a moderate application of P fertilizer (80 $kg \cdot ha^{-1}$ Maxfos: 20% P).

The experimental variables included five cowpea genotypes ('Bensogla', 'Sanzie', 'Omondaw', ITH98-46 and TVu1509), two cowpea plant population densities (83,333 and 166,666 $plants \cdot ha^{-1}$ at 60 x 40 cm and 60 x 20 cm respectively), and two cropping systems (sole cowpea/sorghum and cowpea+sorghum intercropping). A three factor completely randomised block design was used with four replicates. Plot size was 3.6 x 3.2 m (11.52 m^2). Sorghum was maintained at a uniform density of 55,555 $plants \cdot ha^{-1}$ (90 x 40 cm spacing). In mixed culture, cowpea was sown at 90 x 26.6 cm spacing to give 83,333 $plants \cdot ha^{-1}$ and 90 x 13.3 cm to give 166,666 $plants \cdot ha^{-1}$. Cowpea seeds were inoculated with *Bradyrhizobium* CB756 and planted together with sorghum. The seedlings were later thinned to two per hole. Weeding was done four times manually with a hoe until harvesting. The plants were irrigated with sprinklers every three days up to flowering stage (50 days after planting, DAP) and the frequency was reduced to once every seven days thereafter until maturity. Frequent irrigation was necessitated by the prevailing very high evapotranspiration demands during the summer season.

At physiological maturity, the plants were counted and harvested. Yield assessment was carried from the middle rows of each plot excluding the border rows. Sixteen plants of cowpea were sampled from each plot to determine the number of $pods \cdot plant^{-1}$ and number of $seeds \cdot pod^{-1}$. From the sorghum plots, eight plants were sampled for determination of the weight of $head \cdot plant^{-1}$ and weight of $seed \cdot plant^{-1}$. Both cowpea pods and sorghum heads were manually threshed and allowed to air dry (~ 13% moisture content). Grain yields of cowpea and sorghum were determined from each plot and 100-seed weight and shelling percentage recorded. Mean values of yield components were analysed statistically using a factorial analysis of variance (ANOVA) using the software, STATISTICA 2007 (StatSoft Inc., Tulsa, OK, USA). Fisher's least significant difference was used to compare treatment means at $p \leq 0.05$ (Steel and Torrie, 1980).

The biological efficiency and productivity of intercropped cowpea-sorghum was evaluated by land equivalent ratio (LER; Ofori and Stern, 1987), as given below.

$$LER_c = \frac{Y_{ICc}}{Y_{MCc}};\ LER_s = \frac{Y_{ICs}}{Y_{MCs}};\ LER_T = LER_c + LER_s$$

Where LER_C and LER_S = Partial land equivalent ratio for cowpea and sorghum respectively; Y_{ICc} and Y_{ICs} =

Mass yields per unit area of cowpea and sorghum in mixed culture respectively; Y_{MCc} and Y_{MCs} = Mass yields per unit area of cowpea and sorghum in monoculture respectively; LER_T = Total land equivalent ratio.

Results and Discussion

The number of pods·plant^{-1}, number of seeds·pod^{-1}, and 100-seed weight were significantly ($p \leq 0.05$) lower at 166,666 plants·ha^{-1} compared with 83,333 plants·ha^{-1} (Table 1). However, on an area basis, cowpea seed yield increased as plant population density increased (Table 1). Likewise, high cowpea plant population density reduced ($p \leq 0.05$) the weight of heads·plant^{-1}, 100-seed weight and seed yield of sorghum (Table 2). Implicit in this is, presumably, the inter- and intra-specific competition for site resources typical of high population density treatments.

Intercropping cowpea with sorghum also significantly ($p \leq 0.05$) decreased the number of pods.plant^{-1}, number of seeds.pod^{-1}, 100-seed weight and seed yield of cowpea (Table 1). A similar trend was discernible for sorghum too where the weight of heads.plant^{-1}, 100-seed weight and seed yield were significantly ($p \leq 0.05$) reduced in mixed culture relative to sole sorghum (Table 2). Cowpea seed yield on the average was 2.53 ± 0.12 Mg·ha^{-1} in the sole crop and 1.76 ±0.1 Mg·ha^{-1} in the intercropped plots (Table 1). Previous studies by Nambiar et al. (1983) also reported similar negative effects for cowpea intercropped with sorghum. Seed yield of sorghum at high cowpea plant density also was reduced by 12%. This is consistent with the findings of Vandermeer (1989) who showed that yield components of sorghum were lowered when the population density of soybean in the intercropped plots increased.

Performance of cowpea genotypes varied markedly ($p \leq 0.05$). Shelling percentage, 100-seed weight, and seed yield were higher in the farmer-selected genotypes (‘Omondaw’, ‘Sanzie’, and ‘Bensogla’) relative to the improved variety, ITH98-46 (Table 1). However, number of pods·plant^{-1} was significantly greater in the improved varieties (TVu1509 and ITH98-46). Of the five cowpea genotypes, ITH98-46 gave the lowest (1.68±0.19 Mg·ha^{-1}) and ‘Sanzie’ the highest grain yield (2.53±0.16 Mg·ha^{-1}; Table 1). As regards to sorghum yield, when intercropped with cowpea cultivar TVu1509, it gave significantly higher weight of heads·plant^{-1} and seed yield compared with that of ‘Sanzie’ (Table 2). The observed differences among genotypes grown in mixed culture systems could be attributed to the intrinsic

Table 1. Effect of plant density and cropping systems on growth and yield of cowpea (*Vigna unguiculata* L. Walp) genotypes in Stellenbosch, South Africa.

Treatment	No. of pods·plant^{-1}	No. of seeds·pod^{-1}	100-seed weight (g)	Shelling (%)	Seed yield (Mg·ha^{-1})
Density of cowpea (plants·ha^{-1})					
83,333	20.5±1.1^{a}	11.6±0.5^{a}	10.6±0.3^{a}	70.0±0.9^{a}	1.82±0.08^{b}
166,666	17.2±1.2^{b}	8.1±0.34^{b}	9.3±0.3^{b}	67.0±1.0^{b}	2.47±0.14^{a}
Cropping system					
Sole cowpea	20.4±1.4^{a}	11.3±0.6^{a}	10.4±0.3^{a}	69.8±0.8^{a}	2.53±0.12^{a}
Cowpea+sorghum	17.3±0.8^{b}	8.5±0.4^{b}	9.5±0.3^{b}	67.1±1.0^{b}	1.76±0.10^{b}
Genotypes					
ITH98-46	18.8±2.1^{b}	8.6±1.1	9.2±0.3^{c}	60.5±1.1^{d}	1.68±0.19^{c}
TVu1509	25.1±2.2^{a}	9.7±0.7	7.1±0.3^{d}	66.1±1.2^{c}	2.14±0.19^{b}
‘Bensogla’	15.6±1.4^{b}	10.7±1.0	10.7±0.2^{b}	72.2±0.6^{a}	2.13±0.24^{b}
‘Sanzie’	18.0±1.2^{b}	10.6±0.5	10.8±0.3^{b}	69.6±0.6^{b}	2.56±0.16^{a}
‘Omondaw’	16.6±1.3^{b}	9.7±0.8	12.0±0.2^{a}	74.0±0.7^{a}	2.25±14^{ab}

Values (Mean ± SE, n = 4) followed by dissimilar letters in a column, are significantly different. Data for 2005 and 2006 have been pooled together since they were similar.

Table 2. Effect of plant density and cropping systems on yield of sorghum (*Sorghum* bicolor L. Moench) in Stellenbosch, South Africa.

Treatments	Weight of head·plant^{-1} (g)	100-seed weight (g)	Seed yield (Mg·ha^{-1})
Density of sorghum (plants·ha^{-1})			
83,333	49.82±1.22^{a}	2.22±0.02^{a}	1.58±0.04^{a}
166,666	45.30±1.82^{b}	2.16±0.03^{b}	1.39±0.06^{b}
Cropping system			
Sole sorghum	56.09±0.00^{a}	2.32±0.00^{a}	1.76±0.00^{a}
Sorghum+cowpea	39.03±1.15^{b}	2.07±0.02^{b}	1.21±0.04^{b}
Genotypes			
Sorghum +'Bensogla'	47.01±2.57^{bc}	2.20±0.04	1.46±0.09^{bc}
Sorghum +ITH98-46	48.47±2.19^{ab}	2.21±0.04	1.51±0.07^{ab}
Sorghum +'Sanzie'	45.24±2.93^{c}	2.18±0.05	1.41±0.10^{c}
Sorghum +TVu1509	49.65±2.42^{a}	2.18±0.04	1.56±0.09^{a}
Sorghum +'Omondaw'	47.44±2.50^{abc}	2.20±0.04	1.49±0.08^{abc}

Values (mean ± SE, *n* = 4) followed by dissimilar letters in a column are significantly different. Data for 2005 and 2006 have been pooled together since they were similar.

differences in the ability of different cultivars to access growth resources and compete with associated crops. Similar varietal variations in cowpea yield were reported in mixtures earlier too (e.g., Krasilnikoff et al., 2003).

Interaction effect of density x cropping system was significant ($p \leq 0.05$) on the number of seeds·pod^{-1} (Fig. 1A) and 100-seed weight (Fig. 1B). These parameters were reduced ($p \leq 0.05$) by greater cowpea plant density grown in sole crop situation compared with that of intercropping. Yield components of intercropped sorghum in association with cvs. 'Sanzie' and 'Bensogla' showed greater decrease compared with that of cv. TVu1509.

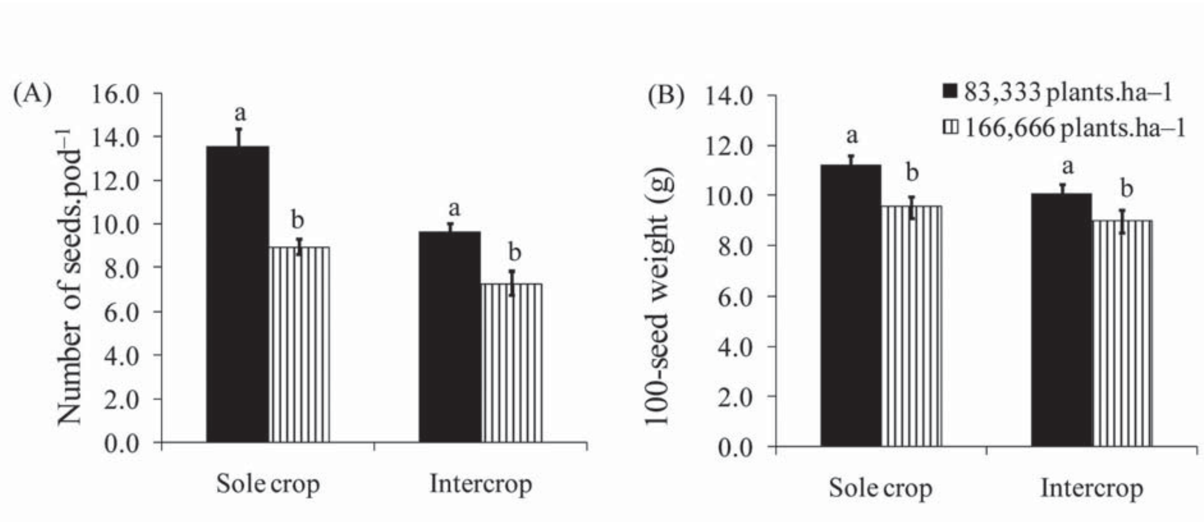

Figure 1. Interactive effects of density and cropping system on number of seeds·pod^{-1} (A) and 100-seed weight (B) of cowpea in Stellenbosch, South Africa.

High cowpea population density reduced total land equivalent ratio (LER_T) compared with low cowpea plant density (Table 3). Regardless of cowpea population density, LER_T values were all greater than 1 (i.e. 1.40 to 1.49), implying a significant yield advantage for the intercropping situations. In other words, 40 to 49% more land would have been required if the component crops were planted as sole crops to obtain the same yield as obtained in the intercropped plots. Our data also showed variations in LER_T among the cowpea genotypes (1.29 to 1.61). Although the highest LER_T value was observed in the 'Omondaw'+sorghum combination, the differences among cultivars were not statistically significant.

Table 3. Effect plant density and cropping systems on the total land equivalent ratio (LER_T) in Stellenbosch, South Africa.

Treatment	LER_T
Density (plants·ha^{-1})	
83,333	1.49±0.05
166,666	1.40±0.06
Cropping system	
'Bensogla'+sorghum	1.29±0.10
ITH98-46 +sorghum	1.47±0.08
'Sanzie' +sorghum	1.42±0.08
TVu1509+sorghum	1.44±0.07
'Omondaw' +sorghum	1.61±0.06

Data for 2005 and 2006 have been pooled together since they were similar. Treatment differences were not statistically significant (p=0.5).

In conclusion, greater population density of plants and intercropping would improve the overall profitability. Intercropping, however, reduced the yield of the component crops, when considered separately. Of the five cowpea genotypes, cv. 'Sanzie' was more productive than other genotypes. Yield of sorghum grown in mixture with cv.TVu1509 and ITH98-46 was higher compared with other cowpea cultivars.

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