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Effects of intercropping on the performance of sorghum (cv Segaolane) and cowpeas in Botswana

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Abstract

Field experiment was conducted at Botswana University of Agriculture and Natural Resources (formerly Botswana College of Agriculture) from March-July 2016 to evaluate effects of intercropping on the performance of sorghum (segaolane) and cowpeas (black eye) in Botswana. The design of the experiment used was a complete randomized block design (CRBD) with five treatments including two controls (sole crops) each replicated three times. Growth parameters (plant height, number of leaves and canopy spread) and grain/seed weights were determined on five pre-determined plants from each plot and the collected data was subjected to analysis of variance (ANOVA). Generally, the number of leaves, plant height and canopy spread for both cowpeas and sorghum were non-significant ($p>0.05$) across the treatments for the first six weeks after planting except for significant number of leaves for sorghum. The following weeks cowpeas and sorghum intercrop showed significant ($p<0.05$) differences in number of leaves, plant height, canopy spread with 50%/50% cowpeas and sorghum revealing superior absolute numbers most of the time. However, sorghum exhibited reduced growth in plant height and canopy spread across treatments which was non-significant ($p>0.05$) until termination. Weights of cowpeas in 50%/50% and 25%/75% intercrop of cowpea and sorghum were significantly ($p<0.05$) higher whereas, 75%/25% intercrop of sorghum and cowpeas had significantly ($p<0.05$) higher weights for sorghum. Based on the findings, 50%/50% intercrop of cowpeas and sorghum, and intercrop of 75%/25% sorghum and cowpeas are recommended as the most desirable cropping systems.

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Introduction

Botswana is characterized by poor soils with declining fertility due to continuous cereal cropping without adequate use of fertilizers. Farmers in the sub-Saharan African region including Botswana are being denied high crop yields because they cannot afford to purchase inorganic fertilizers to replenish nutrient-depleted soils. The declining soil fertility coupled with unreliable rainfall has increased the risk of crop failure in sole cropping systems in the region (Kermah *et al.,* 2017).

The decline in yields due to low soil fertility presents the need for smallholder farmers in the sub-Saharan African region to develop more sustainable production systems (Massawe *et al.,* 2016). Intercropping is a systems that has long been practices by smallholder farmers in various tropical and sub-tropical regions worldwide (Banik *et al.,* 2000; Harggard-Nielsen *et al.,* 2001; Tsubo *et al.,* 2005; Dhima *et al.,* 2007; Dahmardeh *et al.,* 2010; El Naim *et al.,* 2013; Brooker *et al.,* 2015).

This system involves the simultaneous or sequential growing of two or more crops in the same piece of land (Andrew and Kassam, 1976; Willey, 1990; Hauggaard-Nielsen *et al.,* 2008) and is a potential beneficial system of crop production (Naim *et al.,* 2013) which could mitigate risks associated with crop failure (Kermah *et al.,* 2017). Compared to a sole cropping system, cereal-legumeintercropshave shown to improve soil fertility and yields, control weeds, diseases, and insects, conserve soil moisture, reduce soil erosion and improve soil microbiology (Stern, 1993; Youyong*et al.,* 2000; Chen *et al.,* 2004; Fageria *et al.,* 2005; Agegnehu *et al.,* 2006; Delin *et al.,* 2008; Yang*et al.,* 2010; Echarte *et al.,* 2011).Cereal-legume intercropping increases yieldscompared with sole crops (Li *et al.,* 2001; Yin *et al.,* 2015; Hu *et al.,* 2016) because one component can enhance the survival and growth of the other component in the system (Chen *et al.,* 2014).

Poor soil fertility is one of the greatest biophysical bottlenecks to increasing agricultural productivity in the Sub-Saharan Africa and hence threatens food security (Mugwe *et al.,* 2009). Intercropping cereals and legumes is a common cropping system (Ofori and Stern, 1987) that helps to maintain and improve soil fertility (Tsubo *et al.,* 2005). Cereal crops such as pearl millet [*Pennisetum glaucum* (L.) R. Br.], maize (*Zea mays* L.), and sorghum [*Sorghum bicolor* (L.) Moech] are the dominant cereal crops and often intercroppedwith legume crops such as beans (*Phaseolus vulgaris* L.) Walp.], soybean [*Glycine max* (L.) Merr.], groundnut (*Arachis hypogaea* L.), pigeon pea [*Cajanus cajan* (L.) Millsp.] and cowpea [*Vigna unguiculata* (L.) Walp.] (Tsubo *et al.,* 2005). Cereal-legume intercrops has a greater nutrient use efficiency because legume have the ability to fix atmospheric N and make available to the cereal crop (Fujita *et al.,* 1992; Jensen, 1994; Hauggaard-Nielsen *et al.,* 2009; Dedoussac and Justes, 2010; Musa *et al.,* 2012; Dwivedi *et al.*, 2015; Hossain *et al.,* 2016), thus resulting in higher yield of cereal crop than when it is not intercropped (Ndakidemi, 2006; Amanullah *et al.,* 2007).

In addition, the recycling of N-rich residues returns nutrients to the soil (Jensen, 1994) and this is important in maintaining soil fertility in poor soils (Hauggaard-Nielsen *et al.,* 2008).

Prior studies reported that in addition to improving soil fertility, cereal-legume intercropping has higher land use efficiency, lower water consumption and more ecological and environmental benefits compared to a sole or cereal-cereal intercropping (Siddique *et al.,* 2001; Li *etal.,* 2011).

The difference in the competitive ability for growth resources in the cereal-legume component crops also improves crop productivity (Midmore, 1993; Morris and Garrity, 1993; Tsubo *et al.,* 2001).Combinations involving crops with slightly differing growth duration e.g. millet and sorghum or mixtures of early and late maturing varieties of some species are used in areas with growing seasons of variable length to exploit the occasional favourable season yet insure against total failure in unfavourable seasons (Rao,

1986).One of the most important reasons why small holder farmers intercrop is to minimize the risk against total failures and get different produce for their household food and income (Ofori and Stern, 1987; Sullivan, 2003). The present study was conducted to evaluate effects of intercropping combinations of sorghum cowpeas
for the Botswana crop production environment.

Materials and methods

Experimental site

The study was conducted in the field at the Botswana University of Agriculture and Natural Resources (BUAN) formerly Botswana College of Agriculture, Sebele campus during 2016 growing seasons. Sebele is located between latitude 24°33'S and longitude 25°54'E at an elevation of 994 m above sea level.

The climate of Sebele is semi- arid with an average annual rainfall (30 year mean) of 538 mm. Most rain falls in summer, which generally starts in late October and continues to March April.

The soils are shallow, ferruginous tropical soils, mainly consisting of medium to coarse grain sands and sandy loams with a lower water holding capacity and subject to crusting after heavy rains. They are deficient in phosphorus, have low levels of mineral nitrogen and low organic matter content.

Experimental design

The design of the experiment used was a complete randomized block design (CRBD) with five treatments including two controls (sole crops) each replicated three times. Each treatment occupied 3.0 m × 3.0 m plot, spaced 0.5 m apart. Sole treatments were spaced as follows; sorghum at 50 cm (inter-row) × 30 cm (intra-row); cowpeas at 50 cm (inter-row) × 20 cm (intra-row).

The intercropping combinations were as follows; 100% cowpeas, 50% cowpeas & 50% sorghum, 75% cowpeas & 25% sorghum, 25% cowpeas & 75% sorghum and 100% sorghum for treatment 1-5 respectively.

Cultural practices

Land preparation involved uniform cultivation to make a fine seedbed using digging fork, spade and rake. Crops were watered when necessary to keep the medium moist throughout the study. Weeds were removed by hand hoeing and hand pulling as they were found. Regular cultivation was done with hand fork to avoid soil pan formation. Seedlings were also scouted daily for incidences of pests and diseases.

Measured parameters

Plant height was measured by taking the heights of plant above the soil surface at weekly intervals using a meter ruler, the numbers of leaves were counted weekly after true leaves had fully grown or expanded. Canopy spread was measured at weekly intervals across the tips to the widest leaves using a meterruler. Attermination, threshing and cleaning of the grains and seeds was done manually. Grains and seeds were air dried to constant weight and the weight of 1000 grains of sorghum and 100 seeds of cowpeas drawn from the grain/seed yield measured using an electronic analytical balance (Model: PW 124) was recorded.

Data analysis

Collected data was subjected to analysis of variance (ANOVA) using Analytical Software (2003). Where a significant F-test was used and means comparison tests carried out using Least Significant Difference (LSD) at at $p \leq 0.05$.

Results and discussion

Number of leaves

The number of leaves for cowpeas across treatments did not show any significant differences ($p > 0.05$) in the first seven weeks however, some significant differences were revealed across treatments for sorghum in the first seven weeks (data not shown).

From weeks eight to fifteen (termination), cowpeas and sorghum intercrop showed significant ($p < 0.05$) differences in number of leaves with 50%/50% cowpeas and sorghum significantly increasing the number of leaves (Table 1).

Table 1. Effect of intercropping on some growth parameters for both cowpeas and sorghum.

Intercropping	Number of leaves		Plant height (cm)		Canopy spread (cm)	
	Cowpeas	Sorghum	Cowpeas	Sorghum	Cowpeas	Sorghum
100% cowpeas	44.67[b]	-	46.33[b]	-	46.00[c]	-
50% cowpeas & 50% sorghum	61.33[a]	8.33[a]	53.00[a]	69.00	76.67[a]	62.33
75% cowpeas & 25% sorghum	59.33[a]	8.00[a]	53.00[a]	60.67	63.33[ab]	64.33
25% cowpeas & 75% sorghum	47.00[b]	7.33[b]	54.67[a]	63.67	53.00[bc]	63.67
100% sorghum	-	7.33[b]	-	60.33	-	57.00
Significance	*	*	**	ns	**	ns
LSD 0.05	11.09	0.58	3.54	ns	13.74	ns
CV (%)	10.46	3.72	3.42	5.90	11.51	5.17

** Highly significant at $p<0.01$, * significant at $p<0.05$, ^{ns} non-significant at $p>0.05$. Means separated by Least Significant Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.

This is supported by Iderawumi (2014) who observed that the number of leaves in maize and cowpeas increased from week 9 until week 12 after planting. Smallholder farmers frequently use intercropping and other forms of mixed cropping as an important strategy for coping with climate variability (Hassan and Nhemachena, 2008; Ozor and Cynthia, 2010). The advantage of intercropping is more efficient utilization of the available resources and increased productivity (Ofori and Stern, 1987; Gallagher *et al.,* 1999; Hassan and Elasha, 2008; Hamid Alla *et al.,* 2014) soil conservation (Anil *et al.,* 1998), weed control (Poggio, 2005; Banik *et al.,* 2006) and increased yield (Anil *et al.,* 1998; Chen *et al.,* 2004) compared with each sole crop of the mixtures. Amos *et al.* (2012) reported the highest vegetative biomass when legumes were intercropped with maize.

Plant height

Plant height is an important component which helps in the determination of growth (Muranyi and Pepo, 2013). Non-significant ($p>0.05$)treatment effects were revealed for the first six weeks across the treatments for cowpeas (data not shown).

Table 2. Effect of intercropping on cowpeas and sorghum1000 grain weights.

Intercropping	Cowpeas	Sorghum
100% cowpeas	22.36bc	-
50% cowpeas & 50% sorghum	24.79a	43.45a
75% cowpeas & 25% sorghum	22.30c	24.58b
25% cowpeas & 75% sorghum	24.03ab	46.40a
100% sorghum	-	38.36a
Significance	*	*
LSD 0.05	1.72	12.28
CV (%)	3.68	16.09

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

This result is in agreement with Alhaji (2008) who recorded no significant effect for both sole and intercropped cowpeas height. Ndiso *et al.* (2017) reported no significant difference between plant height of sole cowpeas crop and intercropped cowpeas. This could probably mean that there was no competition yet for the resources during the early stages of growth for all the treatments. The result show that six weeks after planting all treatments revealed an increase in height of cowpeas with the intercrop 25%, 50% and 75% treatments significantly increasing the plant height (Table 1). Aliyu and

Emechebe (2006) concluded that any difference in plant height between intercropping and monoculture would indicate a competition for growth factors during the vegetative development of the crop. Although there was significant plant height increase in sole sorghum (data not shown), the following weeks of growth exhibited reduced growth in height of sorghum in all treatments which was non-significant across treatments until termination (Table 1).

The height advantages of intercropping over sole cropping could probably be attributed to increase in the complementary use of growth resources (Agegnehu *et al.*,2006; Aminifar and Ghambari, 2014) such as N and light in space and time (Jahansoon *et al.*, 2007; Liu *et al.*, 2017). The maximum height in sole sorghum at early stages could probably be attributed to penetration of light, circulation of and comparatively more nutritional area under competition-free environment (Ahmad *et al.,* 2007). But contrary to the early observation of increase in height of sole sorghum, thenon-significance response of all treatments could be due to other environmental factors that developed. Other researchers noted that microclimatic variations in intercropping system caused the same response in all treatments (Ghambari *et al.,* 2010). Rafay *et al.* (2013) though reported that sorghum intercropped with cowpeas exhibited potentiality and recorded high value of plant height and grain yield per plant.

A similar response to treatments was revealed for canopy spread for both cowpeas and sorghum with intercropped cowpeas outperforming the sole cowpeas whereas, a non-significant treatment effect was recorded for sorghum (Table 1). Competition and other environmental factors could be the attributing factors.

100 seed weight (cowpeas) and 1000 seed weight (sorghum)

The study shows that the 100 seed weight of cowpeas in 50%/50% and 25%/75% cowpeas and sorghum intercrop were significant higher (Table 2). The implication of these results are that in these arrangements, the cowpeas benefitted greatly from the environmental resources perhaps with minimal interplant competition. Hamd Alla *et al.* (2014) observed that cowpeas intercropped with maize increased height and 100 grain weight. In an earlier study, Legwaila *et al.* (2012) found that there were no significant differences in the weight of cowpeas seeds treatments in cowpeas and maize intercrop.Chakma *et al.* (2011) supported this where there was no significant difference in weight of a pop-corn mungbean/cowpeas intercropping system.

Table 2shows increase in 1000seed weight of sorghum in all treatments except the 25%/75% sorghum/cowpeas intercrop. Similar results were reported by Singh and Ahuja (1990) who observed a yield increase as a result of intercropping sorghum with cowpeas. The yield advantages of sorghum could be due to the partial Land Equivalent Ratios (LER) which had significantly shown the advantage of sorghum over pure stand (El Naim *et al.*, 2013).

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Conclusion

Intercropping is a potentially beneficial cropping system and Botswana smallholder farmers are no exception in practicing system. Different results have been reported from other studies in different intercrop arrangements. From this study it can be concluded that grain weight for cowpeas in 50%/50% and 25%/75% intercrop of cowpeas and sorghum improved. The above intercrop arrangements proved to be superior in most parameters measured. Our results show a good potential for sorghum-legume intercropping for smallholder farmers in Botswana, particularly under more marginal conditions.

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