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Agronomic Performance of Sorghum after Panicle Removal

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Authors' contributions

This work was carried out in collaboration between the authors. Authors GML and KS designed the study. Author KS carried out field and laboratory work. Authors GML, TM and WM reviewed literature and managed manuscript. Author TM managed statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

A field study was conducted at Botswana College of Agriculture (BCA) farm to investigate the effect of panicle removal and no panicle removal on growth, yield and yield components of grain sorghum within and across landraces. The experiment was arranged in a complete randomized block design (CRBD), three landraces, two management practices and four replications. The sorghum landraces; segaolane, korwane and mmamokotane designated (T_1-T_3) represent management practice 1 (panicle removed) whereas controls designated (C1-C3) represent management practice 2 (panicle not removed) were planted in an area of 63 m^2. Within landraces, treated (panicle removed) plants revealed significantly ($P<.05$) lower plant height, number of tillers and grains per head across the landraces. Overall, a non-significant ($P<.05$) treatment effect was observed for total grain weight and shoot biomass. Untreated plants (panicle not removed) significantly ($P<.01$) increased the harvest index in segaolane whereas a non-significant treatment effect was observed

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for korwane and mmamokotane. Across landraces, panicle removal significantly (P<.05) enhanced mmamokotane plant height and shoot biomass whereas it significantly (P<.01) increased the number of grains per head in segaolane. Panicle removal significantly (P<.01) increased total grain, 1000 seed weight and harvest index in korwane whereas a non-significant treatment effect was observed for number of tillers across the landraces. It is concluded that panicle removal is ineffective management practice for enhancing growth, yield and yield components in sorghum landraces.

Keywords: Agronomic traits; panicle removal; management practices; sorghum landraces.

1. INTRODUCTION

Sorghum is one of the major food cereal crops and is ranked fifth after rice, wheat, maize and barley in terms of importance and production [1]. Sorghum is the main food grain for over 750 million people living in the semi-arid tropics of the world [2-5] receiving annual rainfall of 400 to 800 mm [6].

In Botswana sorghum is the most prominent field grain crop [7] and is widely cultivated in different agro-ecological zones, predominantly in dry areas where other crops can survive least. Studies in the north eastern part of Botswana revealed that majority of the farmers (96%) produce sorghum for consumption [8]. IITA [9] also reported that 52% of people in northern Botswana consume sorghum-based food daily. Sorghum is often grown in course-textured soils of low fertility [10]. According to Barimavandi et al. [11] plant leaves are major source of photosynthesis and obtain assimilates for growing parts. In the production of cereal crops, there are many agronomic and physiological manipulations done to increase the yield. Among the management and manipulations of sorghum is the removal of the primary panicle with the expectation that it will increase the grain yield by promoting the tillers [10]. However, removing excessive panicles may reduce crop yield, and yield reduction is higher if panicle removal coincide with the pollination stage [12-14]. Some small-holder farmers in Botswana remove some sorghum panicles with hope to increase yield. Inflorescence or panicle is the terminal growth point in grasses [15]. When the panicle is cut, plants develop some other survival mechanisms and starts channelling the photosynthates to different directions hence developing many stems [16]. According to Langer [17] tillering depends on availability of carbohydrates and their interaction with auxins.

In sorghum, wheat, barley and oats, yield is improved through increase in tillering which can be initiated by removing the panicle of the main stem [17]. According to Bryant et al. [18] removal of panicle from the main stem triggers tillers and as a result yield will be low as most of them fail to reach physiological maturity to produce grains. Studies on panicle removal are lacking. Therefore, the present study was undertaken to evaluate the effect of panicle removal on growth, yield and yield components of sorghum landraces.

2. MATERIALS AND METHODS

2.1 Study Site

The field experiment was conducted in Botswana College of Agriculture (BCA) farms, Sebele, 10 km north of Gaborone city during the 2013/14 ploughing season. The site lies on latitude 24°33'S and longitude 25°54'E elevated and 994 m above sea level. The climate of the area is semi-arid with an average rainfall (30 year mean) 538 mm. Most rainfall received starts in late October continuing to March-April. The soils in the experimental site are sandy loams.

2.2 Experimental Design

The experiment was arranged in a complete randomized block design (CRBD), three landraces, two management practices and four replications. The sorghum landraces; segaolane, korwane and mmamokotane designated (T_1-T_3) represent management practice 1 (panicle removed) whereas controls designated (C1-C3) represent management practice 2 (panicle not removed) were planted in an area of 63 m^2. This include the two outer rows which were used as the guard rows. The main culm panicles were removed just above the flag leaf immediately after full emergence. The spacing was 0.25 m between the plants and 0.75 m between the rows as shown in Fig. 1. Ten plants were tagged from each treatment to be used for data collection.

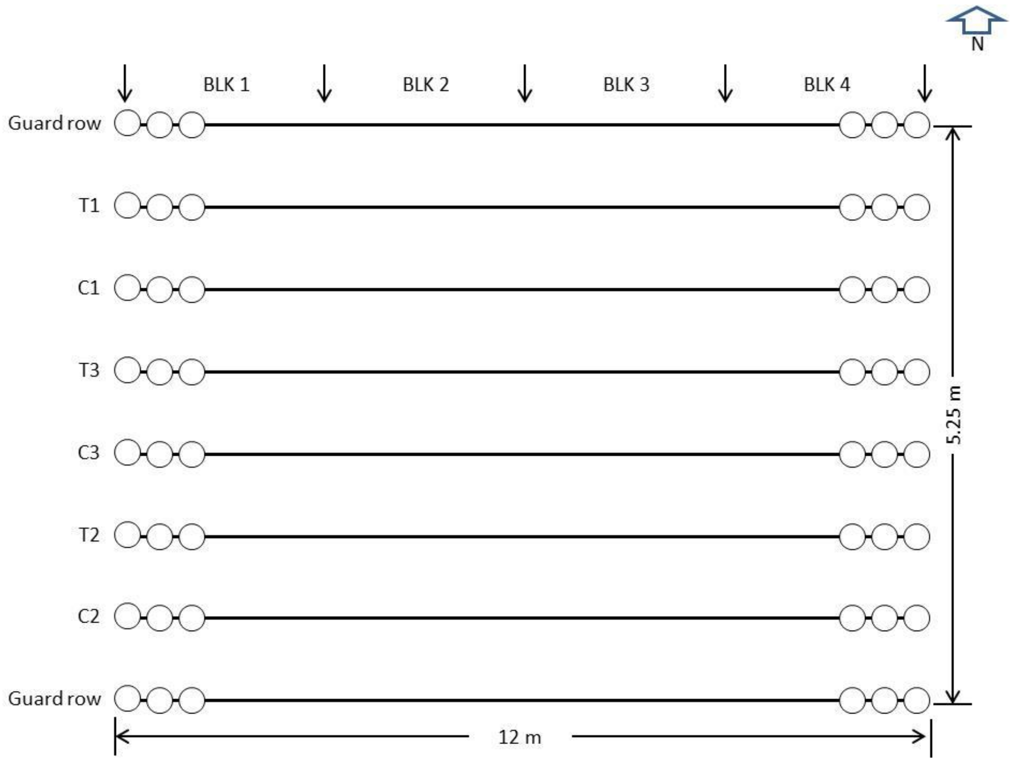

Fig. 1. Sketch of the experimental layout. Where N and BLK are north and block, respectively. Treatments were randomly allocated within the blocks but only shown in BLK 1

2.3 Land Preparation

The soil was cultivated using a digging fork to improve water infiltration. All the plant residues were removed during cultivation of the soil. Irrigation was done to improve soil moisture before planting.

2.4 Planting and Management

Planting was done in the early spring (early October) to utilise the early rainfall. Experimental units were watered wherever there was a need to keep the soil moist throughout the study. Weeds were removed by uprooting every time they appeared in the experimental units for the entire duration of the study. No fertiliser was applied and sorghum heads were covered with net shade to reduce bird damage during the formation of grain at first dough stage.

2.5 Performance Indicators

Data was recorded for agronomic traits, plant height, number of tillers, 1000 grain seeds weight, and number of grains per head. Thereafter, bio yield and harvest index were calculated.

2.5.1 Plant height

Plant height was measured by taking the heights of plant above the soil surface at weekly intervals using a measuring tape until termination of the study.

2.5.2 Number of tillers and grains per head

Tillers were quantitatively determined by counting at the base of the culm weekly. Sorghum head were harvested from the tagged crops. Each head weighed and oven dried to constant weight at 80°C using a hot air oven (Scientific Series 2000). The dry matter for each head obtained and then threshed for a single head and the grains counted. The numbers of grains per head were recorded. This was determined at the end of the study.

2.5.3 1000 seeds weight

After threshing, sorghum heads and recording grains per head, 1000 seeds were counted and weighed using an electronic balance (PGW 4502e) at the end of the study.

2.5.4 Bio yield

Total biomass, expressed as percentage was obtained by harvesting selected plant and fresh weight was measured using a weighing balance (model: PGW 4502e). The samples were then oven dried to constant weight at 80°C using a hot air oven (Scientific Series 2000) and dry weight was recorded. This was determined at the end of the study.

2.5.5 Harvesting index

Harvest index or the ratio of yield biomass to the total cumulative biomass was calculated as dry grain weight over shoot dry weight. This was determined at the end of the study.

2.6 Data Analysis

Collected data was subjected to analysis of variance (ANOVA) using the STATISTIX-8 program. Where a significant F-test was observed and means comparison test was carried out using Least Significant Difference (LSD) at $P \leq .05$. T-test was performed to compare the performance of each sorghum landrace when panicle was removed and when the panicle was not removed.

3. RESULTS AND DISCUSSION

3.1 Effect of Panicle Removal and No Panicle Removal on Some Growth, Yield and Yield Components of Sorghum Landraces

3.1.1 Plant height, number of tillers and grains

The effect panicle removal on plant growth is complex [19] and may be stimulatory or inhibitory [20-22]. Table 1 shows that plant height, number of tillers and grains per head were highly significant at $P<.01$ for segaolane and korwane. The same was revealed in mmamokotane for number of grains per head. A significant ($P=.045$) and non-significant treatment effects were observed in plant height and number of tillers for mmamokotane, respectively. Overall, control plants (panicle not removed) performed better in plant height and number of grains per head across all the landraces whereas treated plants (panicle removed) performed better in number of tillers for segaolane and korwane (Table 1). Taiz and Zeiger [23] reported that hormones such as gibberellins regulated plant height stimulated internodal elongation whereas in treated plants (panicle removed), the hormone stimulated the production of more tillers at the base of internodes. However, panicle removal did not increase the number of tillers for mmamokotane statistically.

3.1.2 Total grain weight per head, shoot biomass and harvest index

Overall, there were no significant differences statistically in total grain weight per head, shoot biomass and harvest index for the three landraces. However, the control (panicle not removed) revealed slightly higher absolute values (Table 1). This is in agreement with Legwaila [10] who found no effect of panicle removal on vegetative dry matter accumulation in sorghum.

3.2 Response of Sorghum Landraces to Panicle Removal

3.2.1 Plant height

There was a significant ($P=.038$) treatment effect on plant height across the sorghum landraces (Table 2). Mmamokotane produced plants that were significantly taller than the other two sorghum landraces. The increased plant height in mmamokotane could probably be due to its genetic makeup and that it used more nutrients in the elongation of the internodes. Panicle removal in this study was partial and probably did not reach the threshold of having an effect on plant height especially of segaolane and korwane Shorter plants observed in segaolane and korwane could also be due to less assimilates produced and distributed to organs of the sorghum plants that have been removed.

3.2.2 Number of tillers and grains per head

Increased tillering may be an adaptive feature that enables crops to tolerate panicle removal by re-establishing lost photosynthetic area and maintaining or even increasing basal area. The number of tillers across the three landraces was not affected by panicle removal and range between 2.0 and 2.15 (Table 2). The effect of panicle removal on the number of grains per head was highly significant ($P=.001$) across the three sorghum landraces (Table 2). Segaolane produced the highest number of grains per head. The number of grains per head varied greatly among the three sorghum landraces (280-800). This could probably be attributed to variations in panicle length, genotype, landrace and site conditions including soil fertility [18]. Xu and Vergara [24] also observed that variability in total grain number in rice cultivar was genetically influenced by growth period and plant height.

3.2.3 Total grain and 1000 seeds weight

The total grain and 1000 seeds weight differed significantly (P=.001) across the sorghum landraces (Table 2). Korwane produced grains that were significantly heavier than the other two sorghum landraces. The variation in grain weights could probably be due to the environment and genetically makeup of the sorghum landraces. Grain filling can be limited either through the supply of photosynthates, source limitation or the capacity of the grain to accumulate available carbohydrate, i.e. sink limitation [25] whichever is lower. The capacity of grain cereals to store starch may be limited by floret cavity-lemma and palea [26] or just the size of sink during grain filling period [27]. Millet [26] correlated heavier kernels in wheat with larger floret cavities. The capacity may be controlled by growth regulators [26]. Brocklehurst [28] associated grain weight to the number of endosperm cells and indicated that the number of endosperm cells was fixed where there was no change in some wheat varieties. Other than environment conditions, mmamokotane with less seed weight could have been influenced by endosperm storing capacity which appears to be limiting.

Table 1. Effect of panicle removal and no panicle removal on some growth, yield and yield components of sorghum landraces

Parameters/ Treatments	Plant height (cm)	Number of tillers	Number of grains/head	Total grain weight (g)	Shoot biomass (%)	Harvest index
Segaolane						
Panicle not removed	123.00±1.33	1.35±0.15	1200.00±26.69	21.37±1.19	82.99±2.32	0.24±0.01
Panicle removed	112.75±1.47	2.15±0.15	800.00±17.95	16.13±0.98	78.41±1.82	0.12±0.01
P value	0.001	0.001	0.001	0.206	0.129	0.001
Korwane						
Panicle not removed	133.00±1.57	1.35±0.15	850.00±26.69	18.41±0.99	64.29±5.68	0.22±0.02
Panicle removed	125.00±2.45	2.15±0.15	500.00±29.69	17.14±0.99	55.27±4.13	0.18±0.01
P value	0.010	0.001	0.001	0.371	0.207	0.157
Mmamokotane						
Panicle not removed	138.90±1.45	2.20±0.09	530.00±26.69	10.02±0.99	87.16±2.06	0.95±0.01
Panicle removed	130.65±3.70	2.00±0.16	280.00±26.69	7.72±0.99	83.44±3.99	0.07±0.01
P value	0.045	0.290	0.001	0.109	0.411	0.120

Means (± standard error) for segaolane, korwane and mmamokotane (panicle not removed and panicle removed) are presented (n=20). T-test (P≤.05) with bilateral independent averages was done

Table 2. Effect of panicle removal on some growth, yield and yield components of sorghum landraces

Landraces	Parameters						
	Plant height (cm)	**Number of tillers**	**Number of grains/head**	**1000 seeds weight (g)**	**Total grain weight (g)**	**Shoot biomass (%)**	**Harvest index**
Segaolane	112.75[b]	2.15	800.00[a]	15.00[b]	16.13[b]	78.41[a]	0.12[b]
Korwane	125.05[ab]	2.15	500.00[b]	16.73[a]	17.14[a]	55.27[b]	0.19[a]
Mmamokotane	130.65[a]	2.00	280.00[c]	7.25[c]	7.72[c]	83.44[a]	0.07[c]
P *value*	0.038	0.166	0.001	0.001	0.001	0.023	0.001

*** Highly significant at P<.01, * significant at P<.05 and ns at P>.05. Means separated by least significance difference (LSD) test at P≤.05, means within columns followed by the same letters are not significantly different*

3.2.4 Shoot biomass

Shoot biomass was influenced by panicle removal across the three landraces (Table 2). Mmamokatane and segaolane had significantly (P=.023) the highest shoot biomass than korwane landrace. The increase in shoot biomass occurred probably because panicle removal triggered assimilates to be re-distributed to other parts of the plant [10]. The partitioning of assimilates to different parts of the plant could be influenced by genes among others. Grain yield in sorghum differ significantly between genotypes [29]. Panicle removal in mmamokotane and segaolane might have changed the photosynthetic characteristics of the remaining tissues [30, 31]. After anthesis, source restriction could have enhanced net photosynthesis rate, stomatal conductance and chrophyll content of mmamokotane and segaolane as observed in wheat [32].

3.2.5 Harvest index

The landraces revealed a highly significant (P=.001) panicle removal response on harvest index (Table 2). Korwane out-performed segaolane and mmamokotane. A yield difference in sorghum is associated with panicles per square metre or per plant, grains per panicle and kernel weight [33]. Grain yield in sorghum may also be described as a function of dry matter accumulation and the amount of dry matter partitioning to the grain. Zhang et al. [34] reported harvest index was positively correlated to water soluble carbohydrates at anthesis and post anthesis dry matter accumulation in wheat. The author further pointed out that increasing the number of grains per square metre by breeding for more weight/spike dry matter, reducing dry matter partitioning to stem and chaff, and re-mobilizing water soluble carbohydrate can lead to improved harvest index.

4. CONCLUSION

Results of the present study indicated panicle removal is ineffective management practice for enhancing growth, yield and yield components in sorghum landraces. The only effect observed was across the sorghum landraces and these were attributed to genetic makeup.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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