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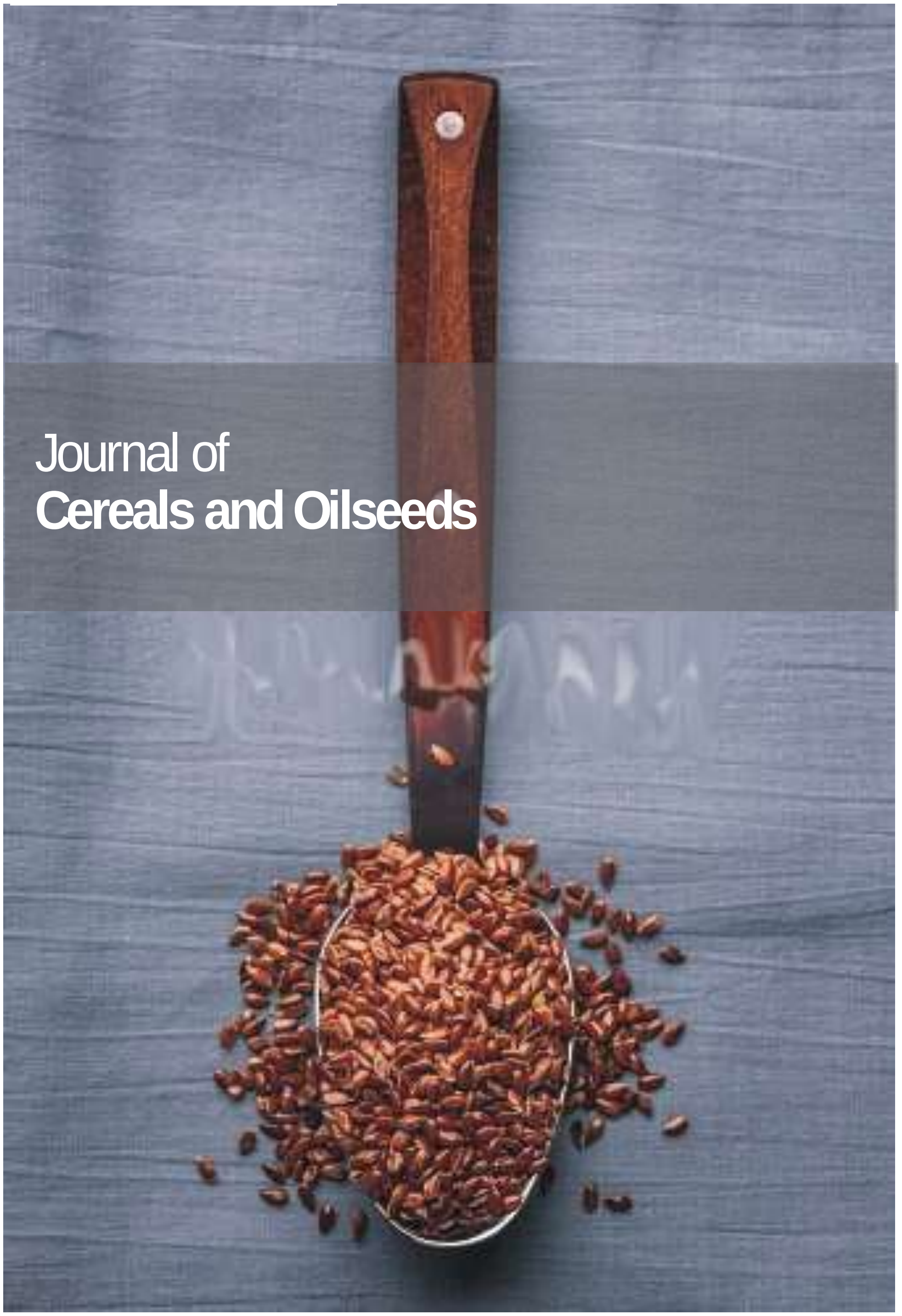

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Table of Contents: Volume 10 Number 2 August 2019

ARTICLE

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Full Length Research Paper

Biomass accumulation and yield expression among winged bean (*Psophocarpus tetragonolobus* L. DC) accessions

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Winged bean accessions were screened to evaluate biomass yield potential. The experiments, carried out during 2015 and 2016 to test nineteen accessions were laid out in Randomized Complete Block Design and replicated three times. Data collected on number of days to 50% flowering (DTF), number of days to 50% pod (DTP), total number of pods (TNP) per plant fresh (FSW) and dry shoot weight (DSW), dry pod weight (DPW), total fresh (TFW) and dry (TDW) weight and seed weight per plot (SWP) were analysed for analysis of variance. Results showed that year of planting significantly (P≤0.01) influenced DTF, DTP and SWP. Accessions exhibited significant variations (P≤0.05) for DFF, DTF, DTP and CP, while no significant interaction was observed between the year and accessions (P>0.05) for all studied traits. FSW had a positive and significant correlation (P≤0.01) with TFW (r= 0.97), DPW (r= 0.87) and TDW (r= 0.78). TFW also had positive and significant correlation (P≤0.01) with DPW (r= 0.68), DSW (r= 0.83) and TDW (r= 0.89). The study revealed that accessions with high biomass accumulation (TPT 12, 11, 53, 5 and 21) are better fit to channel assimilates for yield production through early flowering and pod formation.

Key words: Accession, biomass, seed, yield, winged bean.

INTRODUCTION

Winged bean is a tropical crop that is enriched in protein and is listed as one of the under exploited legumes in the tropics (Amoo et al., 2006) with huge potential as a food source (Mahto and Dua, 2009; Amoo, 1998). The uniqueness of this crop among other leguminous crops is the edibility of all parts of the plant. The protein contained by seeds (30-40%) is comparable to soybean in composition and nutritional value with similar proportions of carbohydrates, oil (15–20%), minerals, vitamins, essential amino acids and other constituents (NAS, 2011; Venketeswaran et al., 1990). Winged bean plant grows primarily as climbing vine with stem and leaves reaching to 3-4 m in height. It is an herbaceous perennial plant but can be grown as an annual crop (Anamika et al., 2011). It has few sustaining tissues in its main stem that limits to a straight growth. In the natural environment, winged bean

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Table 1. List of the evaluated winged bean accessions and their origin.

S/N	Accessions	Source (country of Origin)
1	TPT 2	IITA, Nigeria
2	TPT 3	IITA, Nigeria
3	TPT 4	IITA, Nigeria
4	TPT 5	IITA, Nigeria
5	TPT 6	IITA, Nigeria
6	TPT 10	IITA, Nigeria
7	TPT 11	Sri lanka
8	TPT 12	Sri lanka
9	TPT 14	Unknown
10	TPT 15	Unknown
11	TPT 16	Sri lanka
12	TPT 17	Unknown
13	TPT 19	Unknown
14	TPT 21	IITA, Nigeria
15	TPT 22	Papua New Guinea
16	TPT 26	Papua New Guinea
17	TPT 31	Papua New Guinea
18	TPT 51	Thailand
19	TPT 53	Thailand

Note: IITA means International Institute of Tropical Agriculture.

needs a support to display the leaves under sunlight for efficient photosynthesis. Besides, hormonal effects seem to be related to the position of the stem and further development (Mahto and Dua, 2009). Winged bean is capable of producing exceptional amounts of seed. Despite the benefits derivable from winged bean as an underutilized legume crop, limited study has been carried out on the crop in the areas of the study on its agronomy.

The biomass potential of a new planting material may give information about the material during screening prior to recommendation for different production zones. This approach can be utilized to ensure efficient resource use during screening of materials especially for marginal regions where water and environmental factors may be limiting. This will further help to identify efficient accessions that can channelize the available resources for efficient vegetative growth, flowering and eventual yield. Winged bean production is being advocated in Nigeria because of its nutritional potentials and the prevalence of hidden hunger. However, there is a need to ascertain the suitability of available accessions of winged bean to the production environment of the country. Hence, the objective of this study was to assess 19 winged bean accessions for biomass accumulation and their relation to final yield in the derived savannah agro-ecology of Nigeria.

MATERIALS AND METHODS

The experiment was carried out at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria. Ogbomoso is characterized by two seasons which include the raining season spanning March to October and the dry season which starts in November and ends in February. Temperature ranges from 28 to 33°C and humidity is as high as 74% all year round except for January when the dry wind blows from the North and with a mean annual rainfall of 1,286 mm (Oni et al., 2015; Okotete, 2008). The experimental plot was ploughed twice at two weeks interval to loosen the soil particles to enhance germination. It was subsequently sprayed with a mixture of pre- and post-emergence herbicide to control weed emergence a week before planting. Seeds of nineteen accessions of winged bean (Table 1) were obtained from the Genetic Resources Centre of the International Institute of Tropical Agriculture (IITA), Ibadan. The seeds were scarified mechanically with a scalpel blade to break internal dormancy and hasten germination. The first planting was done between June and December 2015 and the second year planting was done in the same months in 2016. Each accession was sown in three row plots of 4 m each at two seeds per hole. The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Thinning was later done to one plant per stand at 4 weeks after planting (WAP). Staking was done when the plants reached the twining stage by supporting with 3m long dried bamboo poles and the plants were trained to twine around the bamboo stake for access to adequate sunlight.

Agro-morphological data collected included number of germinated seeds (NGS) per plot at 2, 3 and 4 WAP (NGS2WAP, NGS3WAP and NGS4WAP respectively), number of days to first pod and days to 50% flowering (DFF and DTF), number of days to first and days to 50% pod formation (DFP and DTP),total number of pods (TNP) per plant, fresh and dry shoot weight (FSW and DSW) per plant, dry pod weight (DPW) per plant, total fresh and dry weight (TFW and TDW) per plant and seed weight per plot (SWP). A representative plant was chosen on each plot for destructive sampling to enable biomass yield determination. Fresh shoot weight was obtained by

Table 2. Combined ANOVA for vegetative and reproductive variables evaluated for the experiments in 2015 and 2016.

Source	Degree of freedom	Number of germinated seeds 2 WAP	Number of germinated seeds 3 WAP	Number of germinated seeds 4 WAP	Number of days to first flower	Number of days to 50 % flower	Number of Days to first pod	Number of Days to 50 % pod
Year	1	1313.76***	1341.06***	1260.01***	326.75**	870***	1518.04***	3615.47***
Rep(Year)	4	76.62**	45.04**	32.47ns	42.35ns	1.78ns	57.86ns	26.25ns
Accession	18	11.60ns	11.46ns	8.65ns	143.87***	69.16**	131.45ns	160.87**
Year* Accession	18	7.80ns	3.08ns	5.10ns	72.06ns	36.08ns	81.28ns	80.14ns
Error	72	13.56	11.18	12.95	40.61	25.68	82.42	55.85

*, **, *** Data significant at P≤ 0.05, 0.01 and 0.0001, respectively; ns = data not significant at P> 0.05.

cutting the stem at soil level and weighed using a sensitive scale while the dried shoot weight was obtained by drying the enveloped shoot in the oven at 50°C in the laboratory for 48 h and weighed. The same procedure was employed to obtain the fresh and dried pod weight. The collected data were subjected to one way Analysis of Variance (ANOVA) and significant means were compared using the Least Significant Difference (LSD) at 5% probability level. Correlations between pairs of measured variables were computed using PROC CORR in SAS (SAS institute, 2011).

RESULTS

Combined ANOVA results for vegetative and reproductive variables evaluated in 2015 and 2016 are presented in Table 2. The result revealed that accessions had significant variation (P≤0.01) for DFF, DTF and DTP. Year effect also significantly (P≤0.001) influenced all vegetative and yield traits. The combined ANOVA results for partitioned biomass traits evaluated in 2015 and 2016 are presented in Table 3. The results showed that accession had no significant variation for all partitioned biomass traits and yield (P≤ 0.05) while year had significant effect (P< 0.01) for only SWP. The mean values of the vegetative and reproductive parameters are presented in Table 4 while that of the partitioned biomass and seed yield are presented in Table 5. Accession TPT 53 had the highest number of germinated seeds (20.5) at 2 WAP which was significantly higher than the number of germinated seed recorded for TPT 51 (15.5) and TPT 5(15.3) but was not significantly different from the remaining 16 accessions. At 3 WAP, accessions TPT 21 had the highest germination count (20.8), though not significantly different from the mean germination of the other accessions except for TPT 51 and TPT 5 (16.7 and 16.2, respectively). However, at 4 WAP, mean germination of TPT 21 (20.7) was significantly higher than mean values of TPT 11 (16.5), TPT 51 (16.5) and TPT 5 (16.2) but not significantly different from the mean germination of the remaining fifteen accessions. TPT 11 produced first flower at 62 days after sowing (DAS) while TPT 4 produced first flower last at 79 DAS. TPT 16 achieved 50% flowering first at 78 DAS though this was not significantly different from the number of days it took TPT 11, 15, 17, 21 and 51 to achieve 50% flowering while TPT 14 attained 50% flowering latest at 93 DAS. TPT 31 produced its first pod at 93 DAS. TPT 11 however attained 50% pod formation earliest at 94 DAS while TPT 26 reached 50% pod formation at 112 DAS.

The result of fresh shoot weight showed that TPT 5 had the highest values (844.7 g) but not significantly different from the fresh shoot weight of TPT 12 and other accession except those values recorded for TPT 2 (538.3 g), TPT 19 (520.2 g), TPT 10 (450.0 g) TPT 14 (447.7 g), TPT 16 (409.8 g) and TPT 15 (382.2 g). Therefore, TPT 12 had the highest mean total fresh weight (1,694.3 g) which was significantly higher than mean values of most of the accessions except for TPT 19 (1,074.7 g), TPT 10 (982.2 g), TPT 2 (946.5 g), TPT 14 (838.7 g), TPT 16 (797.7 g), and TPT 15 (780.8 g).TPT 12 had the highest mean dried shoot weight (220.7 g) which was significantly higher than mean weight of most of the accessions studied. TPT 12 still had the highest mean total dry biomass weight (438.5 g) which only significantly differed from the mean weight of TPT 2, 14, 15, 16 and TPT 26 (262.5 g, 267.5 g, 260.5 g, 255.8 g and 241.8 g respectively). Furthermore, TPT 12 produced the highest number of pods (41.5) which was not significantly higher than the mean pod number produced by most of the other accessions though TPT 5 had the least number of pods (21.2). Moreover, TPT 12 had the highest fresh pod weight (874.5 g) which was not significantly different from most of the evaluated accessions except for TPT 10, 5, 26, 2, 15, 14 and TPT 16 that had the least fresh pod weight (387.8 g). In addition, TPT 21 recorded the highest mean dried pod weight (251.2 g) that was only significantly different from the mean values of TPT 2, TPT 3, TPT 5 and TPT 26.TPT 12 had the highest mean seed yield per plot (598.8 g) while TPT 21had the least (339.5 g) (Table 5).

The result of Pearson Correlation between every pair of measured variables is presented in Table 6. Number of days to first flowering had strong correlation with number of days to first pod formation (r =0.76; P≤0.01). Also, days to 50% flowering was strongly correlated with days

Table 3. Combined ANOVA for partitioned biomass variables and SWPP evaluated in experiments for the year 2015 and 2016.

Source of variation	Degree of freedom	Total number of pod	Fresh pod weight (g)	Fresh shoot weight (g)	Total fresh weight (g)	Dry pod weight (g)	Dry shoot weight (g)	Total dry weight (g)	Seed weight per plot (g)
Year	1	468.08ns	161665.34ns	3382.82ns	211819.26ns	75717.13ns	18544.88ns	169207.58ns	445562.53***
Rep(Year)	4	128.54ns	282608.68ns	65841.04ns	420287.49ns	2454.67ns	6573.56ns	12010.84ns	22251.40ns
Accession	18	184.36ns	91513.22ns	91851.41ns	298984.56ns	9021.47ns	6061.54ns	18835.96ns	26613.10ns
Year*Accession	18	112.13ns	46192.95ns	78356.42ns	178859.99ns	6709.83ns	5253.82ns	15397.13ns	34008.22ns
Error	72	155.95	80482.2	68164.7	260760	7105.71	4958.73	17562.8	20850.1

*, **, *** Data significant at $P \leq 0.05$, 0.01 and 0.0001, respectively; ns = data not significant at $P > 0.05$.

Table 4. Influence of accession on vegetative and reproductive variables of winged bean.

Accessions	Number of germinated seeds 2 WAP	Number of germinated seeds 3 WAP	Number of germinated seeds 4 WAP	Number of days to first flower	Number of days to 50 % flower	Number of days to first pod	Number of days to 50 % pod
TPT 2	18.5	19.7	19.5	74	87.7	90.2	108.2
TPT3	16.7	17.3	17.7	75.3	87.3	87.7	107
TPT 4	18.7	20.2	19.7	78.7	87.3	89.3	106.7
TPT 5	15.3	16.2	16.2	65.2	84.2	87.7	101.2
TPT 6	17.7	18.3	18	74.7	85.2	86.3	103.2
TPT 10	17	18.2	18	77.3	87	90.2	107.3
TPT 11	16.3	16.8	16.5	62	80	76.5	94
TPT 12	17.3	18.3	17.7	72	84.3	87.3	110.3
TPT 14	17.3	17.3	17.7	74.8	92.5	88	111.7
TPT 15	17.5	18.7	18.5	69.7	82.3	85	103
TPT 16	17.3	17.8	17.8	63.2	78.3	78.7	95
TPT 17	18.3	19	19	70	83	79.5	102.5
TPT 19	17.8	19	18.7	75	90.5	88.5	110.5
TPT 21	19.8	20.8	20.7	66.8	83.2	77.8	100
TPT 22	19.2	19.8	18.3	71	84.7	83.5	100.2
TPT 26	16.8	17.7	17.3	78	88.2	90.8	112
TPT 31	19.5	20.7	18.5	76.5	87	92.8	106.8
TPT 51	15.5	16.7	16.5	70.8	83.7	86.2	101.8
TPT 53	20.5	20	20	72.2	85.8	85	103.3
Mean	17.8	18.6	18.2	72.0	85.4	85.8	104.5
LSD	4.2	3.8	4.1	7.3	5.8	10.4	8.6
CV (%)	20.7	18.0	19.7	8.9	5.9	10.6	7.2

CV = coefficient of variation in %; LSD = least significant difference at $P \leq 0.05$.

Table 5. Influence of accession on partitioned biomass yield of winged bean.

Accessions	Total number of pod	Fresh pod weight (g)	Fresh shoot weight (g)	Total fresh weight (g)	Dry pod weight (g)	Dry shoot weight (g)	Total dry weight (g)	Seed weight per plot (g)
TPT 2	25.0	408.2	538.3	946.5	135	127.5	262.5	510.7
TPT3	25.0	581.3	664.3	1245.7	140.3	148.2	288.5	449.2
TPT 4	29.0	568.7	697.8	1266.5	189.5	150.5	340	438.5
TPT 5	21.2	490.2	844.7	1334.8	141.5	211.5	353	410.7
TPT 6	29.2	577	659.3	1236.3	172	156	328	475.7
TPT 10	24.3	532.2	450	982.2	161.3	126.7	288	532.8
TPT 11	40.3	669.2	595.2	1264.3	240.8	147.3	388.2	444.2
TPT 12	41.5	874.5	819.8	1694.3	217.8	220.7	438.5	598.8
TPT 14	23.5	391	447.7	838.7	164.7	102.8	267.5	448.2
TPT 15	23.2	398.7	382.2	780.8	157	103.5	260.5	374.5
TPT 16	26.5	387.8	409.8	797.7	156.5	99.3	255.8	394
TPT 17	27.2	616.5	572	1188.5	169.5	126.2	295.7	588.3
TPT 19	28.5	554.5	520.2	1074.7	179.5	112.8	292.3	495.5
TPT 21	31.7	643.5	686.7	1330.2	251.2	158.3	409.5	339.5
TPT 22	30.3	672.7	599.3	1272	225.7	143.2	368.8	525.7
TPT 26	22.7	437.5	572.7	1010.2	105.2	136.7	241.8	470
TPT 31	28.2	565.5	608.7	1174.2	158.3	134.2	292.5	497.8
TPT 51	31.5	631.3	643.3	1274.7	216.5	135.3	351.8	503.7
TPT 53	34.2	643.3	587.8	1231.2	201	149	350	475.2
Mean	28.6	560.2	594.7	1154.9	178.1	141.6	319.6	472.3
LSD	14.4	326.6	300.5	587.7	97.0	81.0	152.5	166.2
CV (%)	43.7	50.6	43.9	44.2	47.3	49.7	41.5	30.6

SE = standard error; CV = coefficient of variation in %; LSD = least significant difference at P≤ 0.05.

to 50% pod formation (r =0.79; P≤0.01). Fresh shoot weight had a positive and significant correlation with total fresh weight (r = 0.97; P≤0.01), dry pod weight (r = 0.87; P≤0.01) and total dry weight (r =0.78; P≤0.01). Total fresh weight also had positive and significant correlation with dry pod weight (r = 0.68; P≤0.01), dry shoot weight (r= 0.83; P≤0.01) and total dried weight (r = 0.89; P≤0.01). However, number of days to 50% flowering was negatively correlated with all the biomass traits but was significantly correlated with the pod formation traits.

DISCUSSION

The significant influence of accession on floral traits (flower and pod production) and that of year on all the traits except biomass suggested that growth and yield were greatly influenced by difference in rainfall pattern at the experimental location. In 2015, while the rain started early around April and ended early and fell intermittently, thereby leading to a type of drought termed as random drought (Adebayo et al., 2012). The drought period occurred at 5 WAP, resulting in delayed flowering and pods production in 2015 experimental year. On the other hand, most of the rains in 2016 in the experimental site fell towards the end of the cropping season. This therefore, resulted in the inconsistent performance of the evaluated accessions over the years of the experiment. The observed significant variation in the flowering and yield parameters among the accessions signifies that the accessions performed differently compared with one another and this can be attributed to the occurrence of genetic variation among the evaluated accessions. However, there were rank changes among the accessions between the biomass traits and the yield traits denoting that most of the accessions that performed well for the biomass traits did not perform well for the studied yield traits. The results agreed with the findings of Morakinyo and Ajibade (1998) and Okii et al. (2014) that there is identified variation in performance of a set of genetic materials for different traits. Although, they worked with common bean, they stated that inherent genetic diversity influences morphologically diversity. The non-significant effect observed in biomass traits of all factors (year, accessions, and their interaction) implies that the values obtained from the destructive sampling technique was consistent across the two years of the experiment depicting that despite the occurrence of the drought, the

Table 6. Pearson Correlation between every pair of measured variables of the 19 winged bean accessions.

Variables	DFF	DTF	DFP	DTP	TNP	FPW	FSW	TFW	DPW	DSW	TDW
DTF	0.39***										
DFP	0.76***	0.30**									
DTP	0.30**	0.79***	0.27**								
TNP	0.07ns	-0.09ns	-0.04ns	-0.14ns							
FPW	0.10163	-0.08ns	-0.05ns	-0.09ns	0.76***						
FSW	0.12ns	-0.007ns	0.02ns	-0.03ns	0.55***	0.65***					
TFW	0.12432	-0.05ns	-0.02ns	-0.07ns	0.73***	0.91***	0.97***				
DPW	0.11ns	-0.14ns	0.007ns	-0.22*	0.71***	0.75***	0.47***	0.68***			
DSW	0.13ns	-0.12ns	0.07ns	-0.13ns	0.57***	0.62***	0.89***	0.83***	0.42***		
TDW	0.14ns	-0.16ns	0.04ns	-0.21*	0.77***	0.82***	0.78***	0.89***	0.87***	0.81***	
SWP	0.07ns	-0.28**	0.03ns	-0.33**	0.09ns	0.11ns	-0.03ns	0.04ns	0.06ns	0.02ns	0.05ns

DFF= Number of days to first flower; DTF= Number of days to 50% flower; DFP= Number of days to first pod; DTP= Number of days to 50% pod; TNP= Total number of pod; FPW= Fresh pod weight per plant; FSW= Fresh shoot weight per plant; TFW= Total fresh weight; DPW= Dry pod weight; DSW= Dry shoot weight; TDW= Total dry weight; SWP= Seed weight per plant.

accessions were still able to effectively utilize available resources. Moreover, it revealed that winged bean cultivation can be successfully conducted in the derived savannah agro-ecology without being affected by the random drought.

Evaluated accessions expressed rank changes across the studied traits probably suggesting differential responses of the accessions to the environment. In addition, the observed rank changes among accessions from one trait to the other would make selection for high-yielding and stable accessions challenging. This may be attributed to the likelihood of occurrence of genotype by environment interaction (G × E). The confounding effects of G × E in crop evaluation has been reported by several previous workers (Adebayo et al., 2012; Derera et al., 2008 and Sawkins et al., 2006). The number of germinated seeds was above 90% which suggest that pre-sowing seed scarification is important to achieve improved germination that may have eventually influenced yield, especially due to earlier reports of challenges of germination in winged bean production Aghilian et al., 2014). Thus, superior accessions can be identified and further tried for early germination can be exploited for early maturity.

Early flowering accessions also have higher fresh shoot weight, an indication that accessions with more seed production potentials have strategies to limit vegetative growth and compensate for it by allocating energy to seed production. Also the accessions could have taken advantages of their vegetative ability to accomplish better photosynthesis in favour of pod and seed development resulting from more assimilates reserve generated during physiological activities in the plants. Tourél et al. (2012) mentioned that the timing for flowering period is a determinant factor for the final yield in Bambara groundnut. Hence early flowering may have positively favoured seed production of these accessions. However, early flowering has been noted as a worthy agronomic feature of crops for early maturity, uniformity of yield and crop production in general (Kumaga et al., 2003). Thus accessions that flower early can be considered in the selection of winged bean accessions as it is the practice in other leguminous crops including Bambara groundnut (Onwubiko et al., 2011). The late flowering accessions are characterized by smaller pod and seed yield. It was equally observed that their pods took longer to emerge compared to the rest of the accessions.

The strong correlation coefficients between some traits may allow for simultaneous selections for the traits as well as the use of the related traits interchangeably in selection. The strongly correlated traits are possibly under the influence of the same genes as reported by Miko (2008) and Okii et al. (2014). During germplasm improvement, if two strongly correlated traits are desired, both can be selected simultaneously based on one of the traits. For instance, significant correlation observed between number of days to 50% flowering and number of days to first pod formation suggests that increase in the number of days to 50% flowering could lead to increase in number of days to first pod formation hence selection of accessions with earlier flowering dates for further screenings will enhance reduction in the number of days to maturity of winged bean. In the same vein, number of seeds per pod has negative correlation with flowering dates indicating that late flowering accessions are likely to have lower number of seeds per pod.

Conclusion

Accessions expressed variations for the biomass traits indicates the existence of potentially suitable accessions among the evaluated winged bean accessions for the studied environment. The pre-sowing seed scarifications also resulted in early germinations and some of the accessions had early flowering potentials that could be exploited for early maturity and some of the assessed traits were highly correlated to seed yield. Hence, winged bean production can be favourably conducted within the derived savannah agro-ecological zone for seed production. Accessions TPT 12, TPT 11, TPT 53, TPT 21, TPT 51 and TPT 22 can be subjected to further trials to ascertain stability of yield and performance in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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