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SCREENING OF COWPEA GERMPLASM FOR RESISTANCE TO *Striga gesnerioides* IN NIGER

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ABSTRACT

The parasitic weed, *Striga gesnerioides,* is a major constraint to cowpea production in sub-Saharan Africa. It causes significant yield reductions of cowpea, especially in dry areas. The objective of this study was to evaluate the response of 80 genotypes to *Striga gesnerioides* under natural infestation. The results showed significant variations in the resistance of cowpea lines to *Striga*; lines IT93K-693-2, IT99K-573-1-1 and IT98K-205-8 being free from *Striga* infestation; while lines 2491-171, 2472-154 and Suvita-2 supported few *Striga* shoots. The other lines supported more and varied numbers of emerged *Striga* shoots. The reduction of yield due to *Striga* infestation was more pronounced for the susceptible genotypes as compared to the resistant and tolerant lines. The high level of resistance observed in some breeding lines can be exploited in breeding cowpea for resistance to *Striga.* Principal Component Analysis (PCA) and clustering grouped the genotypes in three main clusters as follow: (i) high yielding and tolerant to *Striga* (ii) moderate yielding and resistant (iii) low-yielding and susceptible.

Key Words: Parasitic weed, *Striga* resistance

RESUME

L'herbe parasitaire, *Striga gesnerioides* est une contrainte majeure de la production du niébé en Afrique subsaharienne. Elle cause des réductions de rendement du niébé très importantes dans les zones arides. Un criblage en vue d'évaluer la réaction de 80 génotypes sous infestation naturelle du Striga a été conduit au champ. Les résultats ont montré qu'il y a des différences significatives dans la résistance des lignées du niébé au Striga. Les lignées du niébé IT93K-693-2, IT99K-573-1-1 et IT98K-205-8 étaient indemnes de pousses émergées du Striga tandis que les lignées 2491-171, 2472-154 et Suvita-2 ont supporté peu de pousses émergées du Striga. Les autres lignées ont supporté des nombres variés de pousses émergées du Striga. L'effet de l'infestation du Striga a entrainé une réduction du rendement des génotypes sensibles comparés aux résistants et aux tolérants. Le niveau élevé de résistance observé chez certaines lignées peut être exploitée dans l'amélioration de la résistance du

niébé au Striga. L'analyse du composant principal et la hiérarchisation ont permis de grouper les génotypes en 3 principales grappes comme suit : (i) hautement productriceset tolérantes au *Striga* (ii) moyennement productrices et résistantes (iii) faiblement productrices et sensibles.
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Mots Clés: herbe parasitaire, *Striga* resistance

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.)Walp.) is an important source of protein for millions of people worldwide. In sub-Saharan Africa (SSA), cowpea is the most grown legume food crop (Timko *et al.*, 2007; Timko and Singh, 2008). All parts of the plant are consumed by humans and animals. In Niger, cowpea is the major food legume and the second most widely grown crop after pearl millet. It is adapted to a wide range of environments, but various biotic and abiotic constraints reduce its productivity in Sub Saharan Africa (SSA). These constraints include insect pests, diseases, parasitic plants and drought.

Striga gesnerioides (Wild.) Vatke, a parasitic flowering plant is one of the main biotic stresses that challenge cowpea production in drought-prone areas. In Africa, yield reduction caused by *S. gesnerioides* is high (83-100%) on susceptible cultivars (Cardwell and Lane, 1995). In Africa five to seven races of *Striga* have been identified (Botanga and Timko, 2006).

The variability in *Striga* virulence due to different races, renders the development of resistant varieties very difficult. A number of management approaches for *Striga* damages are available. These include cultural practices, chemical and biological methods. The most feasible and affordable alternative approach for small-scale farmers is host plant resistance.

Many sources of resistance to the various *Striga* strains were identified in Africa (Atokple *et al.*, 1995a). Local cultivars with good levels of resistance to race 3, include TN121-80, TN93-80, HTR and introductions such as B301 (Botswana landrace), IT97K-499-38, IT97K-499-35, IT82D-849 are being tested in Niger. As these introductions often lack farmers' preferred traits and adaptation to local conditions, breeding for resistance should target specific areas and environments. It is, therefore necessary to find new sources of resistance in the local germplasm or to incorporate resistance genes into farmer-preferred varieties.

The Niger national cowpea gene bank has not been screened for *Striga* resistance, neither have diversity studies conducted on this collection. Research work has mainly focused on testing some improved local materials and introductions, in collaboration with international research institutes such as International Institute of Tropical Agriculture (IITA) and the International Crop Research Institute of Semi-Arid Tropics (ICRISAT). Understanding the diversity among accessions contributes to successful conservation and use of germplasm (Karuri *et al.*, 2010).

A wide genetic base in a germplasm collection provides breeders with important sources of adaptive characters to address climatic and environmental challenges, thus mitigating food insecurity. The objective of the study was to evaluate 80 genotypes mostly from the national cowpea genebank and some introductions for resistance to *Striga generioides* to identify suitable parents for cowpea improvement.

MATERIALS AND METHODS

Germplasm. The germplasm used in this study comprised of 80 genotypes that included 68 landraces and 12 improved genotypes from IITA, Burkina Faso and INRAN (Table 1). Varieties IT93K-693-2, IT99K-573-1-1 and IT98K-205-8 were used as resistant checks;

TABLE 1. Cowpea germplasm screened for the resistance to *Striga gesnerioides*, origin and seed colour, in Niger in 2012

N°	Name	Origin	Colour	N°	Name	Origin	Colour
1	TN 121-80	Niger	Wh	26	B6/15/2367-58	Niger	Mo
2	IT99K-573-1-1	IITA	Wh	27	B5/11/2492	Niger	Wh
3	TN5-78	Niger	Br	28	2450-132 (sac)	Niger	Wh
4	TN88-63	Niger	Wh	29	B5/13/2374-156	Niger	Wh
5	KVx30-309-6G	B. Faso	Wh	30	B3/9/2526-200	Niger	Br
6	Suvita-2	B. Faso	Br	31	2409 (Etq)	Niger	Wh
7	IT93K-693-2	IITA	Br	32	B1/16/2470-152	Niger	Br
8	HTR	Niger	Wh	33	IT90K-372-1-2	IITA	Wh
9	KVx771-10G	B. Faso	Wh	34	TN27-80	Niger	Wh
10	2354 (Etq)	Niger	Wh	35	IT98K-205-8	Niger	Wh
11	B3/13/2399-81 A (1)	Niger	Wh	36	2472-154 (Sac)	Niger	Wh
12	B5/15/2627 (2eR)	Niger	Wh	37	B1/1/2409-91 (1)	Niger	Wh
13	2505 (sac)	Niger	Wh	38	B1/6/2356-38	Niger	Wh
14	2326 (sac)	Niger	Wh	39	2432 (Etq)	Niger	Mo
15	2462-144 (sac)	Niger	Wh	40	B4/1/2381-63 (2eR)	Niger	Wh
16	B4/9/2610 (2eR)	Niger	Wh	41	B3/18/2381-63	Niger	Wh
17	B3/17/2458-140 (2)	Niger	Br	42	B2/16/2378 (1ereR)	Niger	Wh
18	2458-140 (sac)	Niger	Br	43	2491-171 (Etq)	Niger	Br
19	B6/3/392-74	Niger	Wh	44	2510-192 (Etq)	Niger	Wh
20	2367-58 (sac)	Niger	Wh	45	2649-151 (Etq)	Niger	Wh
21	B4/2/2491-171	Niger	Br	46	B3/20/2323 2R	Niger	Wh
22	2374-56 (sac)	Niger	Wh	47	B1/12/2525-234	Niger	Wh
23	2429-111 (sac)	Niger	Wh	48	2372-54 (sac)	Niger	Wh
24	2598 (Etq)	Niger	Wh	49	B5/19/2410-92	Niger	Wh
25	B1/9/2320-02	Niger	Wh	50	B1/5/2354 2R	Niger	Wh
51	2383 (Etq)	Niger	Wh	66	B1/4/2413-95	Niger	Wh
52	B6/14/2472-154	Niger	Wh	67	B2/12/2472-150	Niger	Mo
53	2610 (Etq)	Niger	Wh	68	2432-144 (Etq)	Niger	Wh
54	B4/8/2436-118	Niger	Wh	69	B3/4/2507 (2eR)	Niger	Wh
55	B4/7/2338-20 (2eR)	Niger	Wh	70	B6/2/2516	Niger	Wh
56	2504-186 (Etq)	Niger	Wh	71	2491-191 (Sac)	Niger	Br
57	2420-102 (sac)	Niger	Wh	72	B1/18/2542 (2e R)	Niger	Wh
58	2431-113 (Etq)	Niger	Wh	73	2400-82 2R	Niger	Wh
59	2390-72 (Sac)	Niger	Wh	74	2326 (Etq)	Niger	Wh
60	2392-74 (Etq)	Niger	Wh	75	B3/3/2350-32 (1)	Niger	Wh
61	B1/13/2614-296 (2e R)	Niger	Wh	76	B4/13/2563-245 1R	Niger	Wh
62	B5/12/2462-144 (2eR)	Niger	Wh	77	B2/19/2405-87 (2e R)	Niger	Wh
63	B3/18/2525-30	Niger	Wh	78	B1/14/2473-155	Niger	Wh
64	B4/14/2343-25 (1)	Niger	Wh	79	2477-152 (Etq)	Niger	Br
65	B2/10/2457-119	Niger	Wh	80	2427 (Etq)	Niger	Br

Wh = white; Br = brown; Mo = mottle; B = Faso: Burkina Faso while the varieties TN88-63, TN27-80 and IT90K-372-1-2 were included as susceptible checks.

Experimental procedure. The study was conducted under natural infestation, in fields that were severely infested with *S. gesnerioides*. The experiment was carried out under rainfed conditions in 2012, at Maradi Station (13° 28'N latitude and 7° 10'E longitude) in the Sudano Sahelian zone, in Niger. The experimental set up was a 4x20 α lattice design, with three replications. Each plot comprised of two rows each 3 m long, with plants spaced at 0.80 and 0.50 m.

Three seeds were planted per hill, and were thinned to one per hill two weeks after emergence. Super single phosphate (SSP) fertiliser was applied at a rate of 100 kg^{-1} per hectare, one week before sowing. Two hoe-weedings were done before *Striga* emergence. An insecticide, dimethoate ($C_5H_{12}NO_3PS_2$) was applied at pre-flowering, flowering and after pod formation to control insects at a rate of 1 L ha^{-1}.

Data collection and analysis. Data were collected on number of days from planting to flowering (DFL); number of days from planting to 50% flowering (50% FL); *Striga* shoots per plot (SSP). *Striga* shoots were counted nine weeks after planting (WAP). *Striga* density (DS) was latter computed as the number of emerged *Striga* shoots per plot divided by plot area. *Striga* dry biomass (SDB) was also measured by weighing all the dried *Striga* shoots from each plot. Cowpea pod dry weight (PW) was measured by weighing oven dried (100 °C for 8 hrs) pods from whole plots. Grain yield (GY) was estimated to kg ha^{-1} from weight of seeds obtained per plot. One hundred (100) seed weight (100-SW) was calculated from 100 dry seeds randomly taken from each plot. Fodder yield (FY) was obtained by drying and weighing stems and leaves left after pods were harvested in each plot.

The genotypes were classified as resistant or susceptible using a scale described by Singh and Emechebe (1997) as follows: 1. Resistant = no *Striga* emergence in a plot and no *Striga* symptom observed on plants; 2. Moderately resistant: few *Striga* emergence (2-3) per plot but no *Striga* symptoms observed; 3. Tolerant: Several *Striga* emergences but no significant yield reduction; and 4. Susceptible = 5 to several *Striga* plant emerged per plot and plants show severe *Striga* symptoms. All the data obtained from the trial were subjected to analysis of variance (ANOVA) using PROC GLM in SAS 9.3.

Pearson's correlation coefficients were used to test correlations among the following measured traits 50%FL, DS, SDB, GY, 100-SW and PW using SAS (SAS 9.3). Principal component analysis (PCA) and cluster analysis using the same software were then performed.

RESULTS

There were significant differences ($P< 0.0001$) among the genotypes for all the traits measured (Table 2).

The means of flowering dates, *Striga* density (DS) and dry biomass (SDB), grain yield (GY), 100-seed weight (100-SW) and pod weight (PW) are presented in Table 3.

The number of days to 50% flowering varied from 49 to 73 days, with a mean of 59 days. The number of days to 50% flowering was highest in B5/15/2627 2R (73 days) and lowest in IT98K-205-8 (49 days).

The three resistant checks (IT93K-693-2, IT99K-573-1-1 and IT98K-205-8) had no emerged *Striga* shoots. *Striga* shoots was low in lines 2491-171, 2472-154 and Suvita-2, with mean values of 0.43, 0.74 and 0.87, respectively. These values were significantly different from those of the susceptible check, IT90K-372-1-2 (7.84 *Striga* shoots m^{-2}). Varieties 2491-171, 2472-154 and Suvita-2 were categorised as moderately resistant. Eight lines (B2/16/2378, B1/13/2614-296, B1/4/2413-95, B2/19/2405-87, B1/18/2542, B4/

TABLE 2. Summary of analysis of variance (ANOVA) table for effect of cowpea genotype on selected parameters at Maradi, Niger

Sources of variance	DF	50%	DS	SDB	GY	PW	100-SW
Blocks (Rep)	9	13.67	9.68	86.82	22893.85	13072.69	0.78
Treatments	79	62.42*	13.01*	332.44*	59224.66*	33497.39*	16.90*
Error	149	10.90	5.37	145.95	14718.74	10242.81	0.79
Total	239						

(*) = Significant at 0.0001 probability level; 50%FL = 50% flowering; DS = *Striga* density; SDB = *Striga* density biomass; GY = Grain yield; PW = Pod dry weight; 100-SW = 100 seed weight

7/2338-20, B1/12/2525-234, and B3/13/2399-81A) described as tolerant had high DS (2.53 to 8.77 *Striga* shoots m^{-2}), but no significant yield losses. Ten susceptible lines (B4/13/2563-245 1R, IT90K-372-1-2, B5/15/2627 2R, B1/14/2473-155, B6/2/2516, B2/10/2457-119, B3/3/2350-32, B3/18/2381-63, 2505 and 2510-192) had low to high number of emerged Striga (1.36 to 8.27 shootsm^{-2}).

Cowpea grain yield varied from 54.88 kg ha^{-1} for line 2510-192, to 691.67 kg. ha^{-1} for line B1/18/2542 with an average yield of 246.12 kg ha^{-1}. Only five genotypes (6%) had yield exceeding 500 kg ha^{-1}; while 35 (44%) had yield less than 200 kg ha^{-1}. Yield reductions were significantly high (79 and 66%) in the susceptible cowpea lines, compared to tolerant and resistant lines. In contrast, it was observed that yield of tolerant cultivars (441.17 to 691.67 kg ha^{-1}) was higher than that of the resistant lines (276.63 to 380 kg ha^{-1}). *Striga* dry biomass varied from 0.00 (IT93K-693-2, IT99K-573-1-1 and IT98K-205-8) to 52.88 g (B6/2/2516). The overall genotype mean for SDB was 17.91 per plot.

One hundred cowpea seed weight (100-SW) varied from 7.3 g (2512-192) to 22.25 g (B4/13/2563-245 1R), with a mean of 14.91 g. Cowpea pod weight ranged from 50.93 g (2429-111) to 548.07 g (B1/18/2542 2R) with an average of 195.52 g per plot.

Correlation studies. Table 4 shows correlation coefficients for *Striga* density and dry biomass on yield and yield components. *Striga* density and SDB were not correlated ($P > 0.05$) with yield and yield components. However, *Striga* density was positively and significantly ($P< 0.05$) correlated with SDB ($r = 0.78$) and PW ($r = 0.91$) (Table 4).

Principal component analysis. The first two principal component (PCs) or latent correlation matrices with coefficient values (Eigenvalues) greater than 1.0 are presented in Table 5 together with the percentage of total variability accounted for by each component, and the cumulative percentages. The first two components accounted for 69.68% of the total variance (Table 5). The first PC accounted for 35.48%; whereas the second accounted for 34.19%.

The identification of the components may be achieved by examination of the latent vectors (eigenvectors) for these principal components, but with emphasis on the first two principal components. The first PC with reference to its high value (Table 6), was positively associated with pod weight (PW) and grain yield. The second PC was associated with *Striga* dry biomass (SDB), *Striga* density (DS) and grain yield (GY).

TABLE 3. *Striga* density *and* dry biomass, yield and yield components of cowpea germplasm screened at Maradi in Niger

Genotypes	50% FL (days)	DS (shoot m^{-2})	SDB (g)	GY (kg ha^{-1})	10-SW (g)	PW (g)
Resistant checks						
IT93K-693-2	54.00	0.00	0.00	380.00	15.55	268.40
IT99K-573-1-1	50.33	0.00	0.00	340.74	17.70	170.27
IT98K-205-8	49.00	0.00	0.00	276.63	15.10	248.20
Moderately resistant						
2491-171	58.67	0.43	4.00	258.15	16.80	182.67
2472-154	57.00	0.74	4.45	141.73	16.35	158.67
Suvita-2	63.67	0.87	6.70	244.75	16.75	178.17
Tolerant to *Striga*						
B2/16/2378	61.33	8.77	49.73	502.78	13.80	393.10
B1/13/2614-296	60.00	5.37	23.30	477.16	15.55	263.27
B1/4/2413-95	59.00	5.06	21.60	441.17	14.75	347.73
B2/19/2405-87	58.00	4.5	28.53	476.79	15.45	333.07
B1/18/2542 (2eR)	62.67	3.52	16.70	691.67	17.65	548.07
B4/7/2338-20 (2eR)	61.67	3.46	20.40	561.79	14.50	462.43
B1/12/2525-234	60.00	2.84	28.60	671.05	15.10	521.47
B3/13/2399-81 A (1)	63.00	2.53	11.47	573.21	17.10	458.97
Susceptible checks						
IT90K-372-1-2	57.33	7.84	25.83	150.37	15.55	111.70
TN88-63	61.00	3.89	18.83	230.00	12.75	131.03
TN27-80	59.00	1.67	19.87	170.19	15.75	170.60
Ten most susceptible						
B4/13/2563-245 1R	65.33	8.27	34.70	98.27	22.25	95.47
B5/15/2627 2R	73.00	7.84	42.50	105.62	17.85	91.17
B1/14/2473-155	61.00	7.53	34.13	194.26	14.40	158.17
B6/2/2516	71.33	6.42	31.00	80.93	17.60	68.70
B2/10/2457-119	56.00	6.17	29.56	190.43	11.95	169.77
B3/3/2350-32	67.67	6.05	29.167	163.4	14.1	151.8
B3/18/2381-63	61.33	5.43	30.16	82.90	14.95	79.43
2505	63.33	5.37	20.73	72.41	11.5	56.90
2429-111 (sac)	57.33	1.36	24.63	66.67	11.65	50.93
2510-192	58.67	3.52	19.1	54.88	7.3	62.67
Mean	59.4	3.37	17.91	246.12	14.91	195.52
LSD (P< 0.05)	5.34	3.75	19.39	193.68	1.44	156.65
CV % (5%)	5.58	69.04	67.10	50.06	6.01	51.46

CV = Coefficient of variation (5%); LSD = Least Significant Difference at P = 0.05; 50% FL = days to 50% flowering; DS = *Striga* density; PW = pod weight; SDB = *Striga* dry biomass; GY = cowpea grain yield; 100-SW = one hundred seeds weight

TABLE 4. Correlation coefficients of *Striga* density and dry biomass on yield and yield components

	50%FL	DS	PW	SDB	GY	100-SW
50%FL						
DS	0.17 NS					
PW	-0.05 NS	-0.01 NS				
SDB	0.18 NS	0.78*	0.01 NS			
GY	-0.08 NS	-0.03 NS	0.91*	-0.01 NS		
100-SW	0.03 NS	0.006 NS	0.19 NS	-0.04 NS	0.23 NS	

50%FL = days to 50% flowering; DS = *Striga*density; Pw = pod weight; SDB = *Striga* dry biomass; GY = cowpea grain yield; 100-SW = one hundred seeds weight; (*) the correlation coefficients were significant at P = 0.05; NS = the correlation coefficients were not significant

TABLE 5. Eigenvalues of the Correlation Matrix for the principal components associated with traits of cowpea germplasm in Niger

	Eigenvalue	Difference	Proportion	Cumulative
PC1	2.12896842	0.07734040	0.3548	0.3548
PC2	2.05162802	1.14255976	0.3419	0.6968
PC3	0.90906826	0.15078337	0.1515	0.8483
PC4	0.75828490	0.64364438	0.1264	0.9747
PC5	0.11464052	0.07723063	0.0191	0.9938
PC6	0.03740988		0.0062	1.0000

TABLE 6. Eigenvectors from the two principal component axes used to classified cowpea accessions

	Prin1	Prin2
50% to flowering	-.247130	0.310818
Pod weight	0.531040	0.396442
Striga dry biomass	-.380179	0.524134
100 seed weight	0.268934	0.198453
Striga density	-.398485	0.514312
Grain yield	0.530350	0.409400

Cluster analysis. The agglomerative hierarchical clustering dendrogram (Fig. 1) illustrated the relationship among the 80 accessions based on the traits that contributed most to the first two (2) principal components (Table 6). Three main clusters were identified: cluster A (4 accessions), cluster B (20 accessions) and cluster C (56 accessions). Cluster A included high yielding and *Striga* tolerant varieties; while Cluster B included intermediate yielding and resistant varieties. Cluster C had the low-yielding and *Striga* susceptible lines.

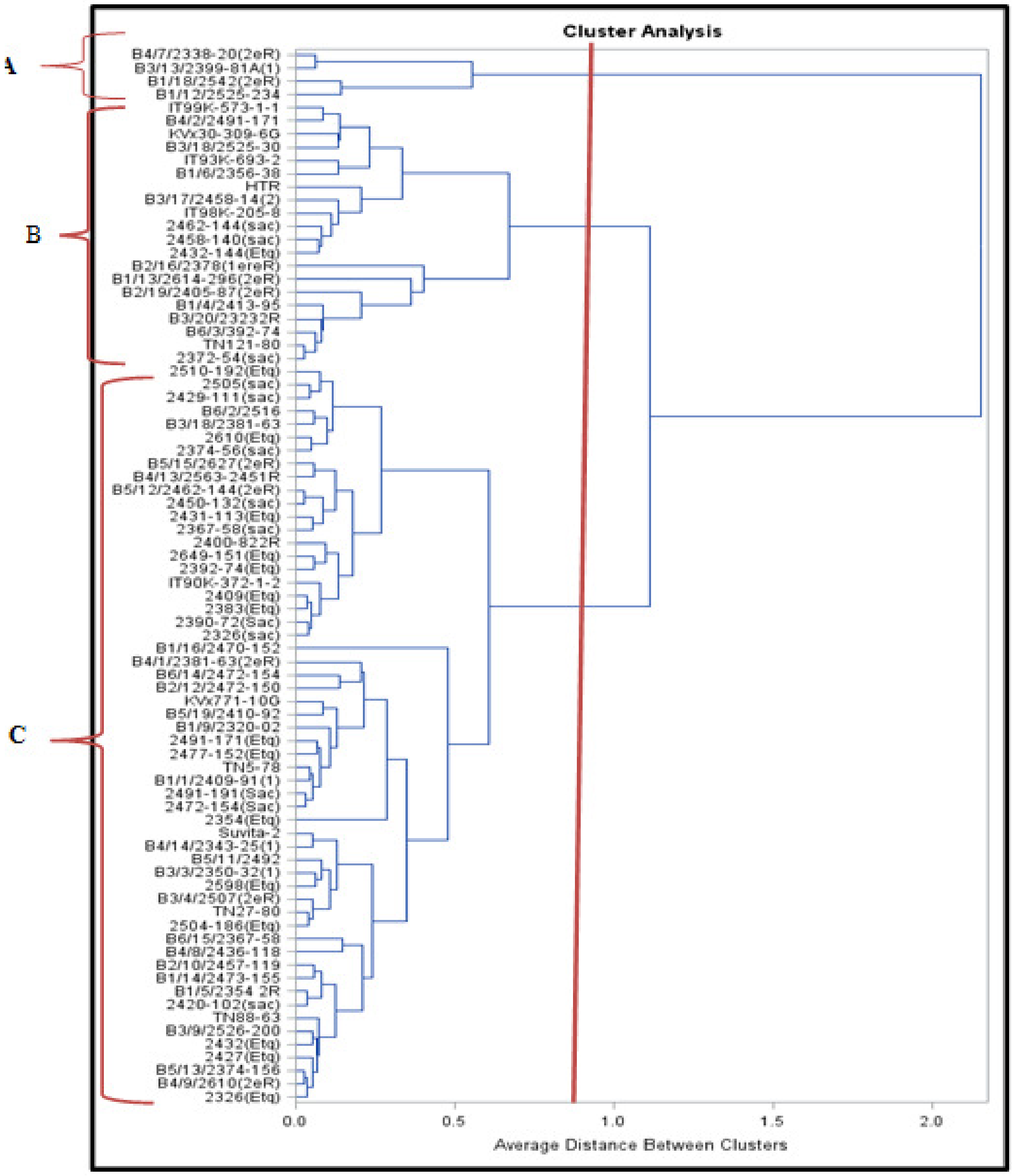

Figure 1. Dendrogram constructed based on yield and *Striga* resistance parameters of cowpea.

DISCUSSION

There was variation in the number of days to 50% flowering among the genotypes (Table 3). This variability may be due to climatic conditions or the genetic background of the varieties. In this study the number of days to 50% flowering ranged from 49 to 73 days after planting with a mean of 59.4. This showed that there were no extra early maturing varieties in the germplasm screened. Early maturity is one of the major criteria for choosing cowpea varieties highlighted by farmers during the participatory rapid appraisal (PRA). Therefore, it is an important breeding goal in the country.

Developing early maturing cowpea varieties in Niger requires introduction of exotic material or screening for earliness in germplasm.

Only three genotypes (IT93K-693-2, IT99K-573-1-1 and IT98K-205-8), included as resistant checks, were free from *Striga* infestation in this study. The resistance in IT93K-693-2 confirmed the results of Singh (2002) and Boukar *et al*. (2004a), who reported that this genotype was resistant to all the five known *Striga* races in Africa. Recently, Tignegre (2010) found similar results with the races prevailing in Burkina Faso. The resistance observed in IT99K-573-1-1 and IT98K-205-8 is in line with the findings of Tchiagam *et al.* (2010), that no *Striga* emerged from the two genotypes screened for the resistance to race 5 in Cameroon. Though, these genotypes have demonstrated high resistance to *Striga* in this study, their grain yields were very low, compared to their yields obtained from studies in Cameroon and in Burkina Faso. IT99K-573-1-1 and IT98K-205-8 yielded 1042.75 and 871.10 kg ha^{-1}, respectively in Cameroon versus 340.74 and 276.63 kg ha^{-1} in Niger, respectively. Line IT93K-693-2 yielded 911.60 kg ha^{-1} in Burkina Faso versus only 380 kg ha^{-1} in this study. The differences observed may be attributed to genotypic response to climatic conditions and soil types. The genotypes are well adapted to conditions in Cameroon. In Cameroon, the study was conducted in the Sudano-Sahelian belt with ferruginous vertisol, and an average annual rainfall ranging from 800-900 mm. The soil is sandy clay, with 8.2 mg kg organic matter and pH 5.65.

In Burkina Faso, the experiment was conducted on station, where the average annual rainfall was 1131 mm. Rainfall at Maradi is about 480 mm and the soil is ferruginous tropical, with a pH of 6.5. This soil contains 12% clay, 5% loam, 4% coarse silt, 77% sand and 2% organic matter (Raynaut *et al.*, 1984). This probably explains the difference in yield observed in the different experiments with the same varieties.

Resistant lines in this present study had lower yield compared to the tolerant lines. Although this is the case, but can be exploited in breeding for resistance to *Striga* cowpea as donor parents.

In contrast, some genotypes such as B2/16/2378, B1/18/2542 and B1/12/2525-234 supported a high number of *Striga* shoots, but performed well for yield, indicating that they are tolerant to *Striga*. These lines are potential sources for breeding for high yield in cowpea.

Out of the susceptible lines, six genotypes gave a significantly lower yield, compared to the weakest susceptible control (IT90K-372-1-2); suggesting that they were highly susceptible to *Striga*. The high number of genotypes for which the yield was less than 200 kg ha^{-1} indicates the inherent low yield of landraces in Niger.

There were no significant correlations between yield components and *Striga* emergence parameters (Table 4). This result is inconsistent with the findings of Kamara *et al*. (2008) in which they reported that yield components were negatively correlated with Striga count. Tignegre (2010), Omoigui *et al.* (2012) and Ekeleme *et al*.(2013) also reported negative correlations between these characters. This shows that *Striga* has a high impact on yield in cowpea. This, however, is not true with tolerant genotypes where high infestation still resulted into high yields. Further some genotypes with the smallest *Striga* population recorded some of the lowest yields.

Information from principal component analyses may guide plant breeders in making selected crosses in a selection programme. The results in this study reveal that out of six parameters used, only four contributed significantly to the variability observed among the genotypes.

Cluster analysis grouped the genotypes into three main clusters: A, B and C. Cluster A was composed of four accessions (B4/7/2338-20 (2eR), B3/13/2399-81 A (1), B1/18/2542 (2eR) and B1/12/2525-234) that were the top yielding and tolerant to *Striga*. The yield of these accessions exceeded 550 kg ha^{-1}. This cluster can be further divided into two sub-clusters of 2 accessions each according to yield. Sub-cluster A1 includes genotypes B1/18/2542 (2eR) and B1/12/2525-234 with a yield exceeding 670 kg ha^{-1}. These can be used as donor parents in breeding for high yield in environments where *Striga* is not a constraint to cowpea production. Tolerant genotypes are discouraged in *Striga* infested areas as they increase seed bank in the soil. Sub-cluster A2 comprises genotypes B4/7/2338-20 (2eR) and B3/13/2399-81 A (1) with a yield exceeding 560 kg. ha^{-1}. Cluster B has genotypes that are moderately yielding and resistant to *Striga.* This cluster too, can be divided into two sub-clusters. B1 comprises genotypes: IT99K-573-1-1, B4/2/2491-171, KVx30-309-6G, B3/18/2525-30, IT93K-693-2, B1/6/2356-38, HTR, B3/17/2458-14 (2), IT98K-205-8, 2462-144 (sac), 2458-140 (sac) and 2432-144 (Etq). On the other hand, sub-cluster B2 included genotypes B2/16/2378 (1ereR), B1/13/2614-296 (2eR), B2/19/2405-87 (2eR), B1/4/2413-95, B3/20/2323 2R, B6/3/392-74, TN121-80 and 2372-54 (sac). Five genotypes classified as tolerant, with high yields and some *Striga* susceptible varieties were grouped in this cluster; meaning that yield parameter contributed greatly in discriminating the genotypes. This was revealed by its high contribution to the first two principal components. Cluster C was composed of the low-yielding and most of the susceptible genotypes. Cluster C can also be partitioned in three sub-clusters according to yield. The sub-cluster C1 included genotypes 2510-192(Etq), 2505(sac), B6/2/2516, B3/18/2381-63, 2610(Etq), 2374-56 (sac), B5/15/2627 (2eR), B4/13/2563-2451R, B5/12/2462-144 (2eR), 2450-132 (sac), 2431-113 (Etq), 2367-58 (sac), 2400-822R, 2649-151 (Etq), 2392-74 (Etq), IT90-372-1-2, 2409 (Etq), 2383 (Etq), 2370-72 (sac) and 2326 (sac). Sub-cluster C2 comprises genotypes B1/16/2470-152, B4/1/2381-63 (2eR), B6/14/2472-154, B2/12//2472-154, B2/12/2472-150, KVx771-10G, B5/19/2410-92, B1/9/2320-02, 2491-171 (Etq), 2477-152 (Etq), TN5-78, B1/1/2409-91 (1), 2491-191 (sac), 2472-154 (sac) and 2354 (Etq). Sub-cluster C3 is composed of genotypes Suvita2, B4/14/2343-25 (1), B5/11/2492, B3/3/2350-32(1), 2598 (Etq), B3/4/2507(2eR), TN27-80, 2504-186 (Etq), B6/15/2367-58, B4/8/2436-118, B2/10/2457-119, B1/14/2473-155, B1/5/2354 2R, 2420-102 (sac), TN88-63, B3/9/2526-200, 2432 (Etq), 2427 (Etq), B5/13/2374-156, B4/9/2610 (2eR) and 2326 (Etq). The moderately resistant genotypes, 2491-171, 2472-154 and Suvita-2 were grouped in this cluster because of their low yield. The above shows that there is genotypic variability between cowpea accessions in this present study, implying that they can be employed in improving the crop for resistance to *Striga* and yield.

CONCLUSION

New sources of *Striga* resistance were not found in the accessions studied. However, genotypes IT93K-693-2, IT99K-573-1-1 and IT98K-205-8 were confirmed as good sources of *Striga* resistance genes. Cultivars B2/16/2378, B1/18/2542 and B1/12/2525-234 are candidates for improving yield. The best combination of crosses to incorporate *Striga* resistance into adapted lines would be IT93K-693-2 as donor parent and the top three farmers' preferred varieties i.e, KVx30-309-6G, IT90K-372-1-2 and TN5-78. The hierarchical analysis grouped the genotypes screened in tolerant and high yielding, resistant and intermediate yielding and susceptible and low yielding.

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