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DIFFERENTIAL AND COMPARATIVE SCREENING OF COWPEA VARIETIES TO *Striga gesnerioides* (WILLD.) VATKE FOR RACE SPECIFIC IDENTIFICATION IN BURKINA FASO

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ABSTRACT

Significant efforts have been made to develop cowpea (*Vigna unguiculata* (L.) Walp.) varieties resistant to *Striga gesnerioides* in Burkina Faso. Despite these efforts, the resistant genotypes developed still express differential responses to *Striga gesnerioides* in different zones of the country. This suggests existence of intraspecific variability within the parasite. The objective of this study was to assess the intraspecific variability of cowpea genotypes to *Striga gesnerioides* infection in Burkina Faso. Ten cowpea varieties were screened over two consecutive years, under artificial infestation with 30 ecotypes of *Striga* seeds at Kamboinsé research station, in a screenhouse in Burkina Faso. Cowpea varieties used included Moussa local, Komsaré and KVx404-8-1, which are susceptible to all *Striga* ecotypes; and varieties B301, IT93K-693-2 and IT82D-849, which are free from all *Striga* ecotypes infestation. Cowpea varieties Tiligré, 524B, local Gorom and Niizwè had specific reactions depending on the ecotypes. The study highlights the existence of varietal specificities according to the geographical origin of *Striga gesnerioides* seeds. The structuring of the intraspecific diversity showed five biotypes, of which three were clearly identified as SG1, SG5 and SG Kp races; and two biotypes could not be identified. Although this study did not allow for a clear determination of the racial affiliation of the two new biotypes, it offers the possibility of developing new strategies to control *Striga* by focusing on the selection of resistant varieties based on regional specificities of *Striga* races in each agricultural zone.

Key Words: Biotypes, *Striga gesnerioides, Vigna unguiculata*

RESUME

Des efforts importants ont été consentis pour développer des variétés de niébé résistantes au *Striga gesnerioides*. Malgré ces efforts, les génotypes résistants développés expriment des réponses différentielles au *Striga gesnerioides* dans différentes zones du pays. Cela suggère l'existence d'une variabilité intraspécifique au sein du parasite. D'où la nécessité d'évaluer la variabilité intraspécifique de *Striga gesnerioides*. Dix variétés de niébé ont été criblées sur deux années successives sous infestation artificielle avec 30 écotypes de *Striga* à la station de recherche de Kamboinsé. Des pots en plastique ont été utilisés comme parcelles expérimentales disposées en blocs de Fisher avec trois répétitions. Les variétés Moussa Local, Komsaré et KVx404-8-1 ont été sensibles à tous les écotypes tandis que les variétés B301, IT93K-693-2 et IT82D-849 ont été exemptes de toute infestation. Les variétés Tiligré, 524B, Gorom local et Niizwè ont eu des réactions spécifiques en fonction des écotypes. L'étude a mis en évidence l'existence de spécificités variétales selon les écotypes. La structuration de la diversité intraspécifique a montré cinq biotypes dont trois ont été clairement identifiés comme les races SG1, SG5 et SG Kp et deux n'ont pas pu être identifiés. Bien que cette étude n'ait pas permis de déterminer l'appartenance raciale des deux nouveaux biotypes, elle offre néanmoins la possibilité de développer de nouvelles stratégies de lutte contre *Striga gesnerioides* en se concentrant sur la sélection de variétés résistantes en fonction des spécificités régionales des races de *Striga* dans chaque zone agricole.

Mots Clés : Biotypes, *Striga gesnerioides, Vigna unguiculata*

INTRODUCTION

The practices of monoculture, the reduction of fallow time or even its abandonment, and above all, the lack of maintenance of soil fertility, has favoured the colonisation of cultivated areas by parasitic phanerogams. Thus, parasite weeds populations have gradually increased and have become serious threats to cereal and cowpea production, particularly in Sub-Saharan Africa.

Parasitic phanerogams are present, but it is in Africa that they constitute a scourge like *Striga*, for which four species are considered dreadful crop pests. These included *Striga aspera*, *Striga Asiatica*, *Striga hermonthica* and *Striga gesnerioides* (Parker, 2009; Csurhes *et al.*, 2013). Since the work of Ouédraogo (1995) and Boussim (2002) on the distribution of the different species of parasitic plants in Burkina Faso and their importance, the *Striga* problem has been on the increase. *Striga gesnerioides*, together with *Striga hermonthica*, are the two most ubiquitous and important *Striga* species causing enormous economic losses to farmers in Burkina Faso.

Striga gesnerioides, which is the subject of this study, is a parasitic plant that causes the premature dieback of cowpea plants. In susceptible cowpea varieties, *Striga gesnerioides* causes yield losses ranging from 30 to 100%, depending on the degree of infestation (Alonge *et al.*, 2005; Kamara *et al.*, 2008; Omoigui *et al.*, 2012).

There is considerable variability in the susceptibility of cowpea cultivars to this parasitic phanerogam (Tignegré *et al.*, 2013; Ohlson and Timko, 2020). Previous work on cowpea improvement for resistance to *Striga gesnerioides* (Ouédraogo *et al.*, 2001; Botanga and Timko, 2006; Li *et al.,* 2009; Tignegré *et al.,* 2013) has encountered great variability in the intraspecific races of the parasite. Studies conducted by Tonessia *et al.* (2009); Li *et al.* (2009) and Omoigui *et al.* (2012) revealed the existence of six races of *Striga gesnerioides* in West and Central Africa. Thus, race SG1 has been identified in Burkina Faso and Togo, race SG2 in Mali, race SG3 in Nigeria and Niger, race SG4 in Benin, race SG5 in Burkina Faso, Cameroon and Nigeria; and race SG6 in Senegal (Li *et al.*, 2009).

For the specific case of Burkina Faso, the present study area, three physiological races have been identified, namely SG1, SG5 and SG Kp (Ouédraogo, 2001; Tignegré *et al.*, 2013). Significant efforts have been made to search for cowpea resistance genes to *Striga gesnerioides* in Burkina Faso (Tignegré, 2010; Ouedraogo *et al.*, 2012). Nevertheless, resistant genotypes continued to have differential responses to *Striga gesnerioides* when moving from one agricultural region to another. This suggests the existence of greater intraspecific variability of the parasite in Burkina Faso. Thus, this study aims at a better understanding of the intraspecific variability and an efficient control of the pest by determining the racial diversity within *Striga gesnerioides* in Burkina Faso. The objective of this study was to determine the intraspecific diversity of *Striga gesnerioides* through differential screening and establish a map of spatial distribution of the different races in Burkina Faso.

MATERIALS AND METHODS

Experimental site. The experiment was conducted during two consecutive years, in June 2018 and August 2019 under artificial infestation in a greenhouse, at Kamboinsé research station in Ouagadougou, in Burkina Faso. This station is located at an altitude of about 296 m.

Collection of seeds of *Striga gesnerioides*. *Striga gesnerioides* seeds used in the study were collected at maturity, in 30 locations across the different agro-climatic zones of Burkina Faso (Table 1). The collection was done from October to November 2017 in naturally cowpea infested fields seed samples, labelled using the site name and the GPS coordinates. Table 1 shows the names of the various localities where *Striga* seeds were collected.

***Striga* sieving technique.** After collecting *Striga* samples, specialised fine sieves were used to separate its seeds from residues (Fig. 1). The seeds were collected in the "receiver" after passing through a mesh size of 212 µm. Sieved seeds were placed in glass jars and stored at room temperature (approximately 25 °C) at the INERA research station in Kamboinsé in Burkina Faso. To prevent seed mixtures between locations, sieving materials were rinsed and disinfected with bleach for at least 30 minutes, before moving from one location to another.

Genetic material. The plant materials comprised of ten cowpea varieties, among which nine had known reactions (Table 2) to the six races of *Striga gesnerioides* identified in West Africa. In addition, 30 ecotypes of *Striga gesnerioides* seeds from different geographical origin were used to screen the cowpea varieties for levels of resistance.

Experimental design and cultural practices. The experimental design was a randomised complete block design, with three replications. The experiment was conducted under artificial infestation in screenhouses, using three litres plastic pots. Each pot was filled to the three-quarters of its volume with a sterilised soil. The sterilisation aimed to destroy any seeds of weeds, mainly *Striga gesnerioides* seeds, which could be in the soil.

The soil consisted of a mixture of clay and sand at the proportions of 30% clay and 70% sand. Then the pots were artificially infested with 0.6 g of *Striga gesnerioides* seeds, corresponding to the minimum quantity of about 10,000 seeds of the parasite.

Striga gesnerioides seeds were pre-conditioned to break their dormancy by watering the infested pots for 14 days before sowing cowpea, as suggested by Husson *et al.* (2008). Two cowpea seeds were sown per pot and 15 days later, seedlings were thinned to one per pot.

TABLE 1. Characteristics of the locations from which the *Striga gesnerioides* seeds were collected in Burkina Faso

Agro-climatic zones	Province	Commune	Ecotype code	GPS coordinates	
North-Sahelian	Soum	Pobé-Mengao	SPM	13°54'17'N	001°44'79'W
North-Sahelian	Séno	Dori	SDN	14°04'65'N	000°03'23'W
North-Sahelian	Séno	Bani	SB	13°42'15'N	000°10'59'W
South-Sahelian	Loroum	Titao	LO	13°40'98'N	001°58'69'W
South-Sahelian	Yatenga	Séguenega	YS	13°28'49'N	001°58'72W'
South-Sahelian	Namentenga	Dargo	NDY	12°36'05'N	000°15'19'W
South-Sahelian	Sanmatenga	Pibaoré	SPO	12°57'72'N	000°54'65'W
South-Sahelian	Sourou	Lankoue	SL	13°12'71'N	002°35'62'W
South-Sahelian	Sourou	Toéni	STD	13°20'69'N	003°12'34'W
North-Soudanian	Fada N'Gourma	Boulontou	FFB	12°08'85'N	000°01'09'W
North-Soudanian	Fada N'Gourma	Kouaré	FK	12°00'77'N	001°19'59'W
North-Soudanian	Fada N'Gourma	Diapangou	FD	12°06'60'N	000°09'129W
North-Soudanian	Boulgou	Tenkodogo	BTe	11°34'3'N	000°23'44'W
North-Soudanian	Kouritenga	Baskouré	KKB	12°13'21'N	000° 19'15'W
North-Soudanian	Kouritenga	Sapaga	KS	12°11'57'N	000°28'04'W
North-Soudanian	Ganzourgou	Zam	GZR	12°18'05'N	000°54'55'W
North-Soudanian	Bazèga	Ipélcé	BI	11°52'32'N	001°33'31'W
North-Soudanian	Bazèga	Toécé	BTo	11°48'14'N	001°15'55'W
North-Soudanian	Oubritenga	Manega	OM	12°49'12'N	01°29'61'W
North-Soudanian	Oubritenga	Zitenga	OZN	12°40'65'N	001°19'42'W
North-Soudanian	Kadiogo	Tintilou	KT	12°12'49'N	001°48'84'W
North-Soudanian	Kadiogo	Kamboinsé	Kb	12°26'59'N	001°33'08W
North-Soudanian	Boulkiemdé	Saria	BSG	12°14'86'N	002°08'32'W
North-Soudanian	Nayala	Toma	NTP	12°46'28'N	002°42'99'W
South-Soudanian	Nahouri	Po	NPO	11°13'48'N	001°17'31'W
South-Soudanian	Zoundwéogo	Nobéré	ZN	11°31'72'N	001°11'70'W
South-Soudanian	Ziro	Sapouy	ZSF	11°25'61'N	001°36'33'W
South-Soudanian	Sanguié	Tita	SPT	11°57'78'N	002°22'81'W
South-Soudanian	Balé	Poura	BPB	11°46'91'N	002°45'38'W
South-Soudanian	Houet	Bama	HB	11° 25'21'N	004° 26'96'W

The experimental design was a randomised complete block design, with three replications. Supplementary watering was done whenever necessary. To reduce fungal attacks, a fungicide treatment (Apronstar) was applied at the 3rd week after sowing at a rate of 5 g l^{-1}.

Data collection. Observations were made on three parameters, namely number of days to first emergence of *Striga* shoot, *Striga* shoot emergence and severity of *Striga* attack. For the number of days to first emergence of *Striga* shoot (DES), observations were recorded daily from the 30th day after planting up to 75th days after planting. As for number of *Striga* shoots emerged per pot, observations were made at 45 (NSSP45), 60 (NSSP60) and 75 (NSSP75) days after planting. With respect to severity of *Striga* attack, assessment was done at 45; 60 and 75 days after planting (SEV45), (SEV60) and (SEV75), respectively, using a scale ranging from 1 to 5 (Singh and

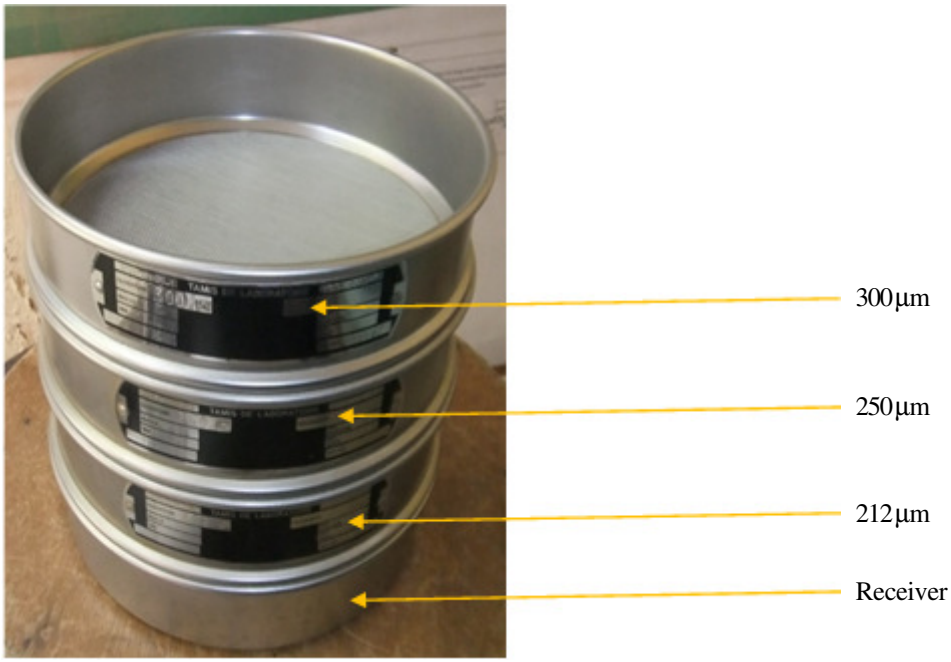

Figure 1. *Striga gesnerioides* sieving material used in the study.

Emechebe, 1997). Each level describing the general condition of the plant and its foliage as follows:

(i) individuals that have not emerged any *Striga* plants (total absence of *Striga*);

(ii) individual having induced the germination and emergence of *Striga* without allowing its development (presence of a few feet of *Striga* that can die before the end of their life cycle);

(iii) presence of several *Striga* plants without visible damage to cowpea plants;

(iv) presence of several *Striga* plants with slight damage to cowpea plants (leaf discolouration, yellowing, stunting, etc.); and

(v) presence of a large population of *Striga* with severe attack followed by death of the cowpea plant.

In addition, the presence of *Striga* was rated 1 and the absence 0. This rating was used to discriminate *Striga* ecotypes based on the differential responses of cowpea varieties according to the geographical origin of *Striga gesnerioides* seeds. Plants that showed *Striga* emergence and development were considered susceptible. Plants free of *Striga* were classified as resistant.

Data analysis. Analysis of variances (ANOVA) and correlation analysis were performed on R software (Rstudio version-1.1.463) for ecotype and ecotype by variety interactions. Means were separated using Student Newman Keuls test, at 5% significance level, whenever the ANOVA test was significant. Cluster analysis was carried out with the presence/absence parameter of *Striga* on cowpea, using the Ward's aggregation method.

RESULTS

Responses of cowpea varieties. The response of cowpea varieties to *Striga gesnerioides* was highly significant for different variables, except for the date of

TABLE 2. Characteristics of the cowpea varieties tested in the *Striga* study during the experiment

Variety	Origin	Seed colour	Maturity cycle	Races of *Striga gesnerioides*							References
				SG1	SG2	SG3	SG4	SG5	SG6	SG Kp	
Susceptible varieties to *Striga gesnerioides*											
Moussa Local	Burkina Faso	White	85	S	S	S	S	S	S	S	Tignegré (2010)
Komsaré	Burkina Faso	White	70	S	S	S	S	S	S	S	Tignegré (2010)
KVx404-8-1	Burkina Faso	White	65	S	S	S	S	S	S	S	Tignegré (2010)
Varieties with differential reaction to *Striga gesnerioides*											
B301	Botswana	brown	70	R	R	R	R	R	R	R	Lane *et al.* (1996); Li *et al.* (2009)
IT82D-849	Nigeria	Red	70	R	R	R	?	R	R	R	Li *et al.* (2009); Tignegré, (2010)
IT93K693-2	Nigeria	Red	70	R	R	R	R	R	R	R	Salifou *et al.* (2017); Tignegré *et al.* (2013)
Tiligré	Burkina Faso	White	70	R	?	?	?	?	?	S	Tignegré *et al.* (2013)
524 B	Burkina Faso	White	70	S	S	R	S	S	S	R	Li *et al.* (2009); Tignegré *et al.* (2013)
Gorom Local	Burkina Faso	Red	70	R	R	S	R	S	R	S	Li *et al.* (2009); Tignegré *et al.* (2013)
Niizwè	IITA	White	65	R	S	R	S	R	S	R	Tignegré *et al.* (2013)

emergence (DES) (Table 3). The number of *Striga* plants emerged per cowpea variety was 0 for resistant varieties and ranged from 0.01 for the less susceptible varieties, to 11.87 for the most susceptible varieties. B301, IT82D-849 and IT93K693-2 showed a good level of resistance to *Striga,* since no *Striga* emergence was observed on these varieties.

Varieties 524B, Tiligré, Gorom Local and Niizwè, however, had different reactions with a relatively low infestation rate (Table 3). The number of *Striga* shoots emerged on these varieties ranged from 0.01 for Niizwè, to 3.07 for variety 524B at 75 days after planting. The varieties which recorded the largest numbers of *Striga* plants on the 75th day after planting were KVx404-8-1 with 3.46; Moussa local with 8.39 and Komsaré with 11.87.

The number of *Striga* shoots emerged and the severity of attacks were significant for both cowpea varieties and the ecotypes of *Striga* (Table 4). The results also showed highly significant differences of genotype by environment interactions, between cowpea varieties and *Striga* ecotypes.

Reaction of cowpea varieties to ecotypes of *Striga gesnerioides*. Results of reaction of cowpea varieties to the different ecotypes of *Striga gesnerioides* are presented in Table 5. Based on these results, some varieties were either susceptible or resistant to all the ecotypes of *Striga* tested. However, four varieties (Tiligré, Niizwè, 524B, Gorom Local) revealed different response to the *Striga* ecotypes. Varieties KVx404-8-1, Moussa Local and Komsaré confirmed their susceptibility by inducing germination of *Striga* seeds, regardless of their provenance. In contrast, varieties B301, IT82D-849 and IT93K-693-2 showed very good resistance to all sources of *Striga gesnerioides* seeds tested, as no *Striga* shoots were observed on them. Varieties Tiligré, Niizwè, 524B and Gorom Local reacted differently to *Striga* infestation depending on *Striga* ecotypes (Table 5). Thus, variety Tiligré showed total resistance to ecotypes from Titao, Toéni and Séguénéga across the two cropping seasons. Variety 524B showed resistance to *Striga* ecotypes from Poura, Saria and Bama. Landrace Gorom Local proved

TABLE 3. *Striga* resistance parameters for the tested cowpea varieties across environment and years

Variables	DES	NSSP45	NSSP60	NSSP75	SEV45	SEV60	SEV75
Moussa local	59,53	0,47abc	2,68b	8,39b	1,18ab	1,67b	2,89b
Tiligré	58,71	0,16abc	0,79cd	1,75cd	1,06b	1,21c	1,45d
Komsaré	56,93	0,73a	4,46a	11,87a	1,25a	2,19a	3,15a
KVx404-8-1	57,94	0,61ab	0,93cd	3,46c	1,36a	1,52b	2,25c
Niizwè	61,50	0c	0,01d	0,01d	1b	1,02c	1,02e
Gorom local	51	0,04bc	0,11d	0,11d	1,06b	1,10c	1,15e
524B	53,47	0,68a	1,56c	3,07c	1,37a	1,64b	2,10c
B301	-	0c	0d	0d	1b	1c	1e
IT93K693-2	-	0c	0d	0d	1b	1c	1e
IT82D-849	-	0c	0d	0d	1b	1c	1e
F-Value	1.55	4.06***	15***	35.26***	8.06***	27.4***	83.7***
Pr > F	0.163ns	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001

DES = Date of emergence of the first Striga plant in each pot in number of days after sowing; NSSP45, NSSP60 and NSSP75 = number of Striga plants emerged in each pot at 45; 60 and 75 days after sowing; SEV45, SEV60 and SEV75 = severity of Striga attacks at 45; 60 and 75 days after sowing

TABLE 4. Mean square and sum of mean squares of the number of *Striga* plants emerged per pot and the severity score assigned to the effects of *Striga* on cowpea

Sum square	df	Mean square			
Source		NSSP	SEV	NSSP	SEV
Replication	2	111	1.33	55.27	0.663
Variety	10	24445***	802.54***	2444.47***	80.254***
Ecotype	31	5618***	79.33***	181.23***	2.559 ***
Variety*Ecotype	300	20638***	332.93***	68.79***	1.106***
Year	1	196	3.36*	196.1	3.359*
Year*ecotype	21	2299**	20.91	109.50**	0.951
Year* variety	8	336	19.05***	42.06	2.381***
Year*Variety*Ecotype	167	13794***	152.89*	82.60***	0.869*
Error	1023	52516	768.28	51.34	0.719

NSSP = number of Striga plants emerged in each pot; SEV: severity of Striga attacks

resistant to most ecotypes, except for the ecotypes of Tenkodogo, Boulontou, Po, Bani, Dori and Nobere. Variety Niizwè was susceptible to only three ecotypes of *Striga,* among which two (Tenkodogo and Boulontou) were common to the other differential varieties.

***Striga* ecotypes by number of *Striga* shoots emerged and the severity of attack.** The analysis of variance showed that the number of *Striga* shoots emerged and the severity score varied according to the origin of *Striga gesnerioides* seeds (Table 6).

Structure analysis of *Striga gesnerioides* diversity. Cluster analysis using data on presence (1) or absence (0) yielded five physiological groups of *Striga* (Fig. 2). Group I was made up of 17 *Striga* ecotypes. Observation of the results in Table 7 shows that among the four different varieties, Gorom local and Niizwè were resistant to ecotypes in group I; while varieties Tiligré and 524B were susceptible to ecotypes in group I. Group II consisted of three ecotypes to which variety Tiligré was susceptible; whereas varieties 524B, Niizwè and Gorom Local were resistant to these ecotypes. Group III was also composed of three ecotypes. All the four different varieties showed susceptibility to the entire ecotypes of this group.

Group IV consisted of three ecotypes, to which only variety 524B was susceptible (Fig. 2). Group V was composed of four ecotypes to which only the variety Niizwè showed resistance. Table 8 presents the recap of the five biotypes of *Striga gesnerioides* derived from the cluster analysis. This grouping gave a general overview of the spatial distribution of the different biotypes of *Striga gesnerioides* in Burkina Faso.

Determination of races of *Striga gesnerioides.* A comparison of the ecotypes of *Striga gesnerioides* characterised in the present study, with the races already described in Burkina Faso, shows that ecotypes in group I, III and V can be identified as races SG1, SG5 and SG Kp, respectively. The ecotype in group II and IV differed from the three known races. The ecotypes of group II preferentially parasitise variety Tiligré. In addition, group III differs from the other four groups because the ecotypes in this group can parasitise all the four varieties, which is not the case for the other groups.

TABLE 5. Number of *Striga* shoots emerged by cowpea variety and per year.

Variety	524B		Gorom local		Komsaré		KVX404-8-1		Moussa local		Niizwè		Tiligré		IT82D-849		IT93K-693-2		B301	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Ecotypes	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP	PSP
BI Ipélcé	1b	nt	0b	nt	5.33b	nt	8.0b	nt	23.0a	nt	0b	nt	2.33b	nt	0b	nt	0b	nt	0b	nt
BPB	0a	nt	0a	nt	13	nt	2.66a	nt	6.66a	nt	0a	nt	1.66a	nt	0a	nt	0a	nt	0a	nt
BSG	2.33b	nt	0b	nt	26.00a	nt	6.00b	nt	22.33a	nt	0b	nt	0.33b	nt	0b	nt	0b	nt	0b	nt
BTe	22,00a	1,33b	2,66a	7,33b	15,00a	23a	9,66a	11,66b	14,33a	10b	0,33a	4,66b	23,66a	0,66b	0b	0b	0b	0b	0b	0b
BTo	0.66b	nt	0b	nt	14.00a	nt	4.00b	nt	0.66b	nt	0b	nt	1.33b	nt	0b	nt	0b	nt	0b	nt
FD	0.33b	22,5a	0b	0b	25.66a	6,66b	1.00b	13,66ab	5.66b	8b	0b	0b	0b	7,33b	0a	0b	0a	0b	0a	0b
FFB	5.66a	13ab	0a	nt	4.00a	14ab	0a	2,66b	2.66a	28a	0a	0b	0a	5b	0b	0b	0b	0b	0b	0b
FK	0.33b	8,33a	0b	0b	15.00a	18a	2.33ab	12a	10.00ab	nt	0b	2a	0b	4,66a	0b	0b	0b	0b	0b	0b
GZR	12.33b	nt	0b	nt	37.66a	nt	0.66b	nt	13.33b	nt	0b	nt	4.66b	nt	0a	nt	0a	nt	0a	nt
HB	0a	0c	0a	0c	8,00a	12c	4,00a	82a	10,33a	69b	0a	0c	0a	13,5c	0a	0c	0a	0c	0a	nt
Kb	0,33a	0b	0a	nt	1,33a	6.33b	0a	1.33b		23a	0a	nt	0a	nt	0a	nt	0a	nt	0a	nt
KKB	0a	0.66b	0a	0a	5.33a	15,5a	0.33a	8a	1.66a	0,5a	0a	0a	2.33a	1,33a	0a	0a	0a	0a	0a	0a
KS	0.33a	6,66a	0a	0a	11.66a	7,33a	5.00a	5a	4.33a	0a	0a	0a	1.66a	0a	0a	0a	0a	0a	0a	0a
KT	8,00a	10a	0a	0a	1,33a	8,33a	4,66a	6a	14,66a	11,66a	0a	0a	0,33a	0,33a	0b	0a	0b	0a	0b	0a
LO	5,66a	7,66a	0a	0b	5,00a	nt	4,00a	1b	4,00a	3.66a	0a	0b	0a	0b	0b	0b	0b	0b	0b	nt
NDY	0b	nt	0b	0a	14,66a	8a	2,33b	9,66a	5,66b	7,33a	0b	0a	0,33b	nt	0b	0a	0b	0a	0b	0a
NPO	1,00b	nt	0b	35,66a	21,33a	35,33a	0,33b	2,5a	12,00ab	19,66a		nt	1,00b	0,66a	0b	nt	0b	nt	0b	nt
NTP	0,66b	3a	0b	0b	10,00b	3.5a	4,33b	0,66b	30,00a	0b	0b	0b	6,00b	1b	0a	0b	0a	0b	0a	0b
OM	0b	6,66a	0b	0b	4,66b	19a	2,66b	4.66b	14,66a	6.66b	0b	0b	0b	1b	0a	0b	0a	0b	0a	0b
OZN	4,33b	1b	0b	0b	19,00a	15a	2,00b	0,66b	8,00b	0,33b	0b	0b	1,33b	0b	0b	0b	0b	0b	0b	0b
SB	0b	nt	0,33b	nt	8,33a	nt	1,66b	nt	2,00b	nt	0b	nt	0b	nt	0b	nt	0b	nt	0b	nt
SDN	0a	1a	0,66a	6,66a	19,00a	11,33a	0,33a	13,33a	13,00a	22,33a	0a	0a	6,33a	65a	0a	0a	0a	0a	0a	0a
SL	0.66a	0,5a	0a	0a	3.33a	5.66a	0.66a	0a	1.66a	4.33a	0a	0a	0a	0a	0a	0a	0a	0a	0a	0a
SPM	9,33a	9,5ab	0a	0b	9,66a	17,5a	7,00a	nt	3,00a	1,33b	0a	0b	0a	4,66b	0a	0b	0a	0b	0a	0b
SPO	4,66ab	nt	0b	0a	9,00a	0,66a	0,33b	3a	1,66b	4a	0b	0a	0b	0,66a	0b	0a	0b	0a	0b	0a
SPT	3,66ab	9a	0b	0a	13,66a	12,66a	1,66ab	21a	14,00a	26a	0b	0a	0b	0,33a	0b	0a	0b	0a	0b	0a
STD	2,33b	3.33ab	0b	0b	9,33ab	1ab	15,33a	4.33ab	9,33ab	8a	0b	0b	0b	0b	0b	0b	0b	0b	0b	0b
YS	0b	4a	0b	0a	9,33a		6,66a	2,66a	7,66a	0,66a	0b	0a	0b	0a	0b	0a	0b	0a	0b	0a
ZN	0b	10,33a	0b	4,5a	14,66a	27a	8,33ab	0.25	4,33ab	24,66 a	0b	0a	0,66b	3a	0b	0a	0b	0a	0b	0a
ZSF	9,66ab	nt	0b	nt	13,66a	nt	1,33b	nt	4,33b	nt	0b	nt	0,33b	nt	0b	nt	0b	nt	0b	nt

NSSP = Number of shoots of Striga emerged; BI : Ipélcé ; BTo : Toécé ; FD : Diapangou ; GZR : Zam ; Kb : Kamboinsé ; KKB : Baskouré ; KS : Sapaga ; KT : Tintilou ; NDY : Dargo ; NTP: Toma ; OM : Manèga ; OZN : Zitenga ; SL : Lankoué ; SPM : Pobé-Mengao ; SPO : Pibaoré ; SPT : Tita ; ZSF : Sapouy ; FK : Kouaré ; BPB : Poura ; BSG : Saria ; HB : Bama ; BTe : Tenkodogo ; FFB : Boulontou ; LO : Titao ; STD : Toénie ; YS : Séguénéga ; NP : Po ; SB : Bani ; SDN : Dori ; ZN : Nobéré

TABLE 6. Number of *Striga* shoots emerged and its severity score over two years of the experiment

Ecotype of *Striga*	NSSP		SEV	
	2018	2019	2018	2019
BI	3,31bc	Nt	1,55bc	nt
BPB	2,4bc	Nt	1,23bc	nt
BSG	5,7abc	Nt	1,43bc	nt
BTe	8,77a	5,11ab	2,1a	2,07a
BTo	2,07bc	Nt	1,7abc	nt
FD	3,27bc	5,24ab	1,17bc	1,75ab
FFB	1,23bc	4,88ab	1,47bc	1,71ab
FK	2,77bc	3ab	1,13bc	1,43ab
GZR	6,87ab	Nt	1,77ab	nt
HB	2,23bc	8,42ab	1,3bc	1,9a
Kb	0,17c	3,33ab	1c	1,43ab
KKB	0,97bc	2,86ab	1,17bc	1,5ab
KS	2,3bc	0,25b	1,37bc	1,25ab
KT	2,9bc	3,4ab	1,07bc	1,77ab
LO	1,87bc	0,4b	1,6bc	1,37ab
NDY	2,3bc	2,62ab	1,5bc	1,72ab
NPO	3,57bc	10,31a	1,33bc	1,86ab
NTP	5,1bc	0,48b	1,17bc	1,21ab
OM	2,2bc	2,68ab	1,27bc	1,55ab
OZN	3,47bc	1,6b	1,33bc	1,43ab
SB	1,23bc	Nt	1,3bc	nt
SDN	3,93bc	5,66ab	1,2bc	1,67ab
SL	0,63bc	1,07b	1,13bc	1,45ab
SPM	2,9bc	2,67ab	1,3bc	1,47ab
SPO	1,57bc	0,67b	1,2bc	1,4v
SPT	3,3bc	5,78ab	1,3bc	1,71ab
STD	3,63bc	1,45b	1,53bc	1,59ab
YS	2,37bc	0,77b	1,2bc	1,59ab
ZN	2,8bc	8ab	1,43bc	1,93a
ZSF	2,93bc	Nt	1,23bc	nt
Means	2,86	3,50	1,33	1,57
F-value	2,2637***	2,7***	2,9865***	2,13**
Pr(>F)	<0,0001	<0,0001	<0,0001	0,001

PSP = number of Striga emerged shoots; SEV = severity of Striga attacks. means followed by the same letters are not significantly different; BI : Ipélcé; BTo : Toécé; FD : Diapangou; GZR : Zam; Kb : Kamboinsé; KKB : Baskouré; KS : Sapaga; KT : Tintilou; NDY : Dargo; NTP: Toma; OM : Manèga; OZN : Zitenga; SL : Lankoué; SPM : Pobé-Mengao; SPO : Pibaoré; SPT : Tita; ZSF : Sapouy; FK : Kouaré; BPB : Poura; BSG : Saria; HB : Bama; BTe : Tenkodogo; FFB : Boulontou; LO : Titao; STD : Toénie; YS : Séguénéga; NP : Po; SB : Bani; SDN : Dori; ZN : Nobéré

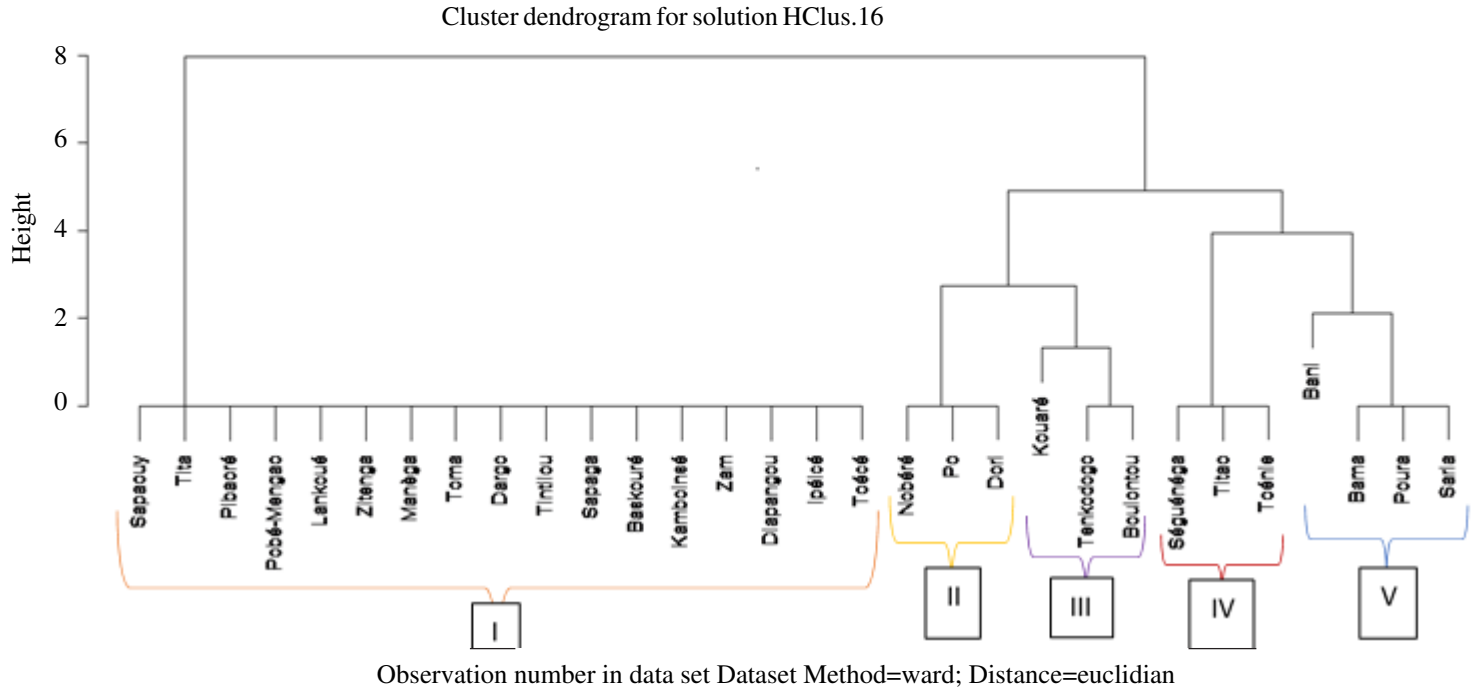

Figure 2. Cluster analysis of *Striga gesnerioides* ecotypes according to Ward's aggregation criteria based on the differential reaction of four cowpea varieties.

TABLE 7. Responses of cowpea varieties to *Striga gesnerioides* ecotypes

Variety	Komsaré	KVx404-8-1	Moussa local	524B	Tiligre	Gorom local	Niizwe	B301	IT82D -849	IT93K -693-2
BI	1	1	1	1	1	0	0	0	0	0
BPB	1	1	1	0	1	0	0	0	0	0
BSG	1	1	1	0	1	0	0	0	0	0
BTe	1	1	1	1	1	1	1	0	0	0
BTo	1	1	1	1	1	0	0	0	0	0
FD	1	1	1	1	1	0	0	0	0	0
FFB	1	1	1	1	1	1	1	0	0	0
FK	1	1	1	1	1	0	1	0	0	0
GZR	1	1	1	1	1	0	0	0	0	0
HB	1	1	1	0	1	0	0	0	0	0
Kb	1	1	1	1	1	0	0	0	0	0
KKB	1	1	1	1	1	0	0	0	0	0
KS	1	1	1	1	1	0	0	0	0	0
KT	1	1	1	1	1	0	0	0	0	0
LO	1	1	1	1	0	0	0	0	0	0
NDY	1	1	1	1	1	0	0	0	0	0
NPO	1	1	1	1	1	1	0	0	0	0
NTP	1	1	1	1	1	0	0	0	0	0
OM	1	1	1	1	1	0	0	0	0	0
OZN	1	1	1	1	1	0	0	0	0	0
SB	1	1	1	0	0	1	0	0	0	0
SDN	1	1	1	1	1	1	0	0	0	0
SL	1	1	1	1	1	0	0	0	0	0
SPM	1	1	1	1	1	0	0	0	0	0
SPO	1	1	1	1	1	0	0	0	0	0
SPT	1	1	1	1	1	0	0	0	0	0
STD	1	1	1	1	0	0	0	0	0	0
YS	1	1	1	1	0	0	0	0	0	0
ZN	1	1	1	1	1	1	0	0	0	0
ZSF	1	1	1	1	1	0	0	0	0	0

"1" presence of Striga; "0" absence of Striga; BI : Ipélcé; BTo : Toécé; FD : Diapangou; GZR : Zam; Kb : Kamboinsé; KKB : Baskouré; KS : Sapaga; KT : Tintilou; NDY : Dargo; NTP: Toma; OM : Manèga; OZN : Zitenga; SL : Lankoué; SPM : Pobé-Mengao; SPO : Pibaoré; SPT : Tita; ZSF : Sapouy; FK : Kouaré; BPB : Poura; BSG : Saria; HB : Bama; BTe : Tenkodogo; FFB : Boulontou; LO : Titao; STD : Toénie; YS : Séguénéga; NP : Po; SB : Bani; SDN : Dori; ZN : Nobéré

Table 8 illustrates the comparison of *Striga gesnerioides* ecotypes in Burkina Faso with races already identified based on the response of cowpea varieties. It is clear that Group I consists of the ecotypes of race SG1, Group V consists of the ecotypes of race SG 5 and Group III consists of the ecotypes of race SG Kp. Based on the reaction of variety Tiligré to the ecotypes of group IV, these ecotypes could be assimilated to race SG1 or determined as a virulent group of race SG1. The distribution of ecotypes according to groups or biotypes is presented in Table 9. Figure 2 shows the spatial distribution of the different races of

Striga gesnerioides throughout in Burkina Faso.

DISCUSSION

The cowpea varieties tested in these experiments revealed the presence of genetic variability among them, as regard to their responses to the different ecotypes of *Striga gesnerioides* (Table 5). The results of the two different screening tests revealed that cowpea varieties had differential responses depending on the origin of *Striga* seeds (Table 5). This different reaction allowed for the characterisation of the thirty ecotypes of *Striga gesnerioides* used in this study. The three susceptible varieties (Komsaré, Moussa local and KVx404-8-1), were consistently susceptible to *Striga gesnerioides* seeds from all the 30 localities. They induced *Striga* seeds germination and shoots emergence for all the 30 ecotypes of *Striga* seeds, indicating that *Striga* seeds were viable and the screening was appropriate. Therefore, the different reactions observed with other cowpea varieties (Table 7) clearly indicate the existence of intraspecific variability within the screened *Striga* ecotypes. Inferring the presence of different biotypes or races within *Striga gesnerioides* in Burkina Faso, which may be related to the geographical zones. In fact, it has been observed that each biotype prevails in a specific area as presented in Figure 2.

Among the cowpea varieties tested, B301, IT82D-849 and IT93K-693-2 were completely free from *Striga gesnerioides* infestation, over the two years of evaluation, and for all ecotypes of *Striga* (Table 5). Several other workers reported similar results showing that these three varieties possess complete resistance against the six races of *Striga gesnerioides* identified in West Africa (Lane *et al.,* 1996 ; Tonessia *et al.,* 2009; Li *et al.,* 2009; Omoigui *et al.,* 2012). The resistances observed in B301 and IT93K-693-2 are consistent with the findings of Tignegré *et al.* (2013) showed that both genotypes were resistant to the three races of *Striga gesnerioides* in Burkina Faso.

TABLE 8. Comparison of *Striga gesnerioides* biotypes from Burkina Faso with the races already identified

Cowpea variety	Identified races							Biotypes in Burkina Faso					Source
	SG1	SG2	SG3	SG4	SG5	SG6	SG Kp	I	II	III	IV	V	
Tiligré	R	?	?	?	?	?	S	S	S	S	R	S	Tignegré *et al.*, 2013
524B	S	S	R	S	S	S	R	S	R	S	S	S	Li *et al.* (2009); Tignegré *et al.*, 2013
Gorom local	R	R	S	R	S	R	S	R	R	S	R	S	Li *et al.* (2009); Tignegré *et al.*, 2013
Niizwè	R	S	R	S	R	S	R	R	R	S	R	R	Tignegré *et al.*, 2013; Salifou *et al.* (2017)

R = resistant, S: susceptible

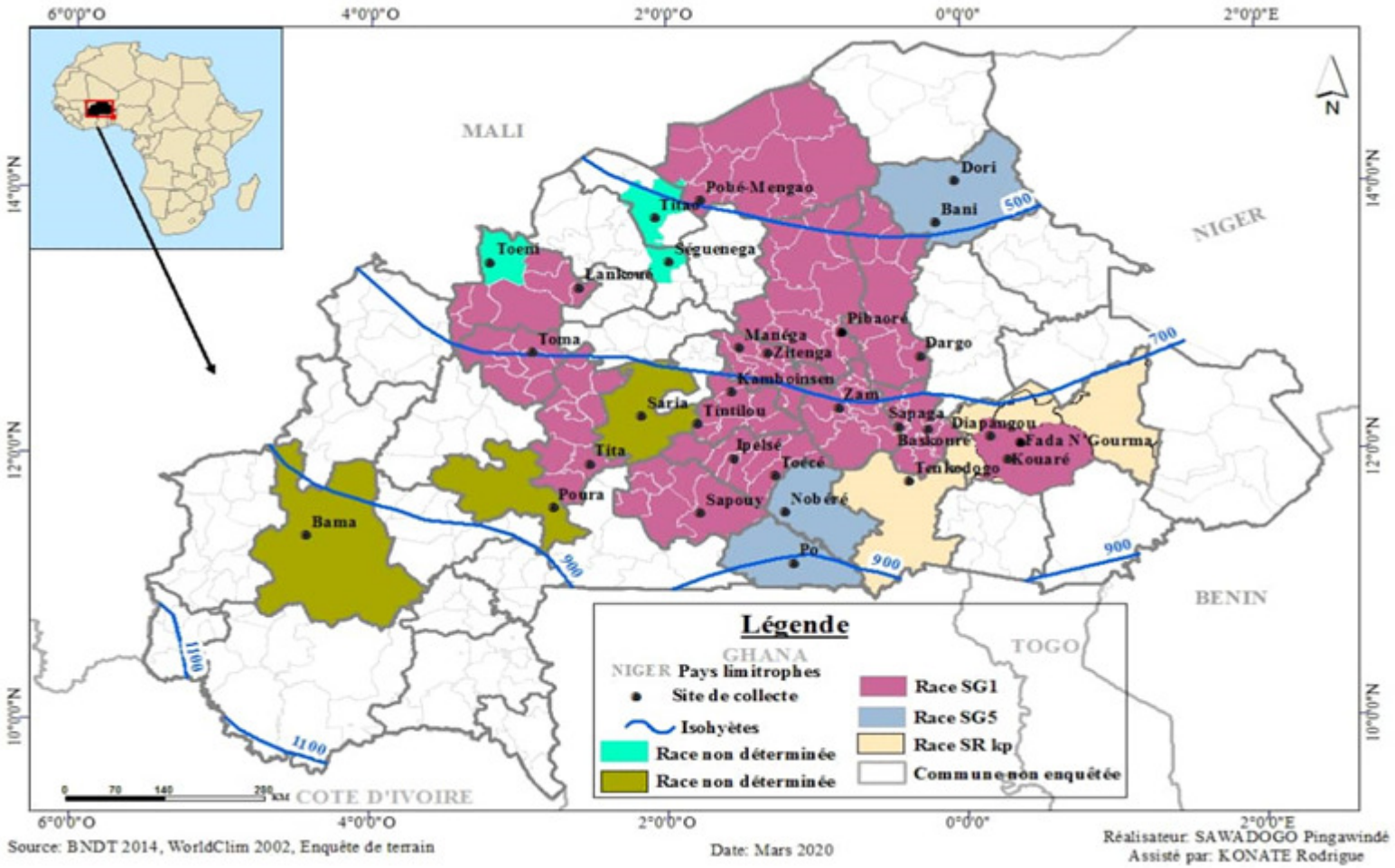

Figure 2. Distribution of the different races (biotypes) of *Striga gesnerioides* identified in Burkina Faso.

TABLE 9. Recapitulation of the different groups of ecotypes of *Striga gesnerioides* obtained from Closter analysis

Class	Number	*Striga* ecotypes	Differential varieties		Physiological races
			Resistant varieties	Susceptible varieties	
I	17	Ipélcé, Toécé, Diapangou, Zam, Kamboinsé, Baskouré, Sapaga, Tintilou, Dargo, Toma, Manèga, Zitenga, Lankoué, Pobé-Mengao, Pibaoré, Tita, Sapouy, Kouaré	Gorom local ; Niizwè	Tiligré ; 524B	SG1
II	3	Poura, Saria, Bama	Gorom local ; Niizwè ; 524B	Tiligré	Undtermined
III	2	Tenkodogo, Boulontou		Tiligré ; Gorom local ; Niizwè ; 524B	SG Kp
IV	3	Titao, Toénie, Séguénéga	Tiligré ; Gorom local ; Niizwè	524B	Undtermined
V	4	Po, Bani, Dori, Nobéré	Niizwè	Tiligré ; Gorom local ; 524B	SG5

Significant responses of cowpea varieties to *Striga gesnerioides* have also been reported in Niger (Salifou *et al.*, 2017). On the other hand, screening tests conducted in different countries has revealed the presence of six intraspecific races of *Striga gesnerioides* in West Africa (Li *et al.,* 2009). In addition to these six races, Tignegré *et al.* (2013) identified another biotype (SG Kp) that occurs in the eastern part of Burkina Faso. However, all the reported races do not occur in the same country; for example, in Burkina Faso, three races of these races (SG1, SG5 and race SG Kp) have been reported (Ouédraogo, 2001; Tignegré *et al.*, 2013). In addition to these three races, two biotypes from different agroecologies have been identified in the country through this study. These ecotypes were collected from agroecologies that were not fully covered by the previous intraspecific variability studies. This would justify why these *Striga gesnerioides* biotypes were not reported in previous studies in Burkina Faso. In addition, a clear differential reaction of cowpea genotypes to these ecotypes was observed (Table 9), implying that they are two new distinct different races of *Striga gesnerioides* occuring in Burkina Faso. As an illustration, variety Niizwè (IT98K-205-8) recognised as resistant to all races of *Striga* in Burkina Faso (Tignegré *et al.*, 2013), was susceptible to *Striga* ecotypes from Tenkodogo and Boulontou. This could be explained by the phenomenon of resistance breakdown in this variety. The race of *Striga* occurring in this area has, therefore, developed a mechanism to overcome the resistance conferred by the variety IT98K-205-8. Though this variety still confers resistance to the other races in Burkina Faso, it is susceptible to races SG2, SG4 and SG6 (Tonessia *et al.*, 2009; Omoigui *et al.*, 2012). However, this study was unable to identify this biotype as one of the above races.

The ecotypes of Saria, Poura and Bama could also qualify as different biotype because of their reaction differences compaired to races SG1, SG5, SG Kp and the previous biotype. This biotype might have evolved from

its alternative hots to the cowpea plants in locations such as Saria, Pouni and Bama. In fact, *Striga* infestation in the western part of the country has been recently observed due to the gradual intensification of cowpea cultivation in this area.

Co-infestation of both cowpea and the alternative host has been reported in these areas (Sawadogo *et al.*, 2020). Cowpea infestation by *Striga* deriving from spontaneous vegetation has been reported by several authors (Boussim, 2002; Tonessia *et al.*, 2009). It is important to note that *Striga* ecotypes from Saria, Pourra and Bama were till now not described in Burkina Faso.

Based on geographical distribution, race SG5 was predominant in the southern part of the country, race SG1 in the northern and central Burkina Faso, whereas race SG Kp was confined in the eastern part (Fig. 2). Race SG1 was the most widespread in Burkina Faso as has been earlier observed that this race was the most widespread in West Africa. This distribution is further consistent with the findings of Ouédraogo (2001) and Tignegré (2010), who worked in the areas of prevalence of race SG1. This geographical distribution has revealed that several races of *Striga* can occur in the same agroecology. Seed dissemination through human activities, animals or water partly explains the co-infestation of two or more races in a particular area. The co-occurrence of several *Striga* biotypes in the same agricultural district could explain why improved varieties for *Striga* resistance are observed to be susceptible to *Striga* in some agricultural areas of Burkina Faso.

CONCLUSION

In the present study, four cowpea varieties (Tiligré, 524B, Gorom Local, Niizwè) have displayed different responses (susceptibility or resistance) to the ecotypes of *Striga gesnerioides* used. Varieties Moussa Local, Komsaré and KVx404-8-1 are susceptible to all ecotypes of *Striga* prevailing in Burkina Faso. The reverse is true for genotypes B301, IT93K-693-2 and IT82D-849. Based on the degrees of reaction of cowpea varieties, the ecotypes of *Striga* used in this study are grouped into five classes, representing different races. Among these races, three are clearly identified as races SG1, SG5 and SG Kp. Two distinct new biotypes have been identified and the geographical distribution map of *Striga gesnerioides* in Burkina Faso established. However, the study did not allow for a clear affiliation of the newly identified races to the other races in West Africa. These results will serve to redefine the deployment of *Striga* resistant varieties across the country.

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