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SOURCE OF RESISTANCE AMONG COWPEA ACCESSIONS TO BRUCHID, *Callosobruchus maculatus* F. Coleoptera: Chrysomelidae, IN BENIN

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ABSTRACT

Post-harvest loss in cowpea (*Vigna unguiculata* L.) is essentially caused by bruchid (*Callosobruchus maculatus* F.), the most damaging storage pest causing up to 95% loss of produce kept for long in non-treated conditions. In managing storage pests, host plant resistance proves to be a better approach than chemicals control, especially for food produce. However, no investigation in Benin has tackled resistance of cowpea germplasm to bruchid. The obective of this study was to identify sources of resistance to cowpea bruchid in Benin. A total of 174 cowpea accessions were evaluated in storage. Fourteen cowpea accessions were found resistant to bruchid including: IT06K-123-1, ALEGI*SECOW3B, IT86D-1038, WC35B, IT86D-1033, TOUMKALAM, KPLOBEROUGE, WC66*NE50, IT06K-270, IT84S-2246-4, WC36, TVU1471, TVU-1367-7 and WC66*5T with respective Dobie susceptibility indices of : 2.96, 2.71, 2.67, 2.58, 2.55, 2.49, 2.46, 2.36, 2.11, 1.42, 1.15, 0.53, 0.00 and 0.00. Pest tolerance of cowpea (0.00 to 100.00%) varied according to the resistance and susceptibility statuses of accessions screened. Correlations showed that seed damage, number of adult emerged, weight loss and Dobie susceptibility index, could be considered essential while selecting bruchid tolerant accessions. The resistant accessions observed during this experiment can serve as parental lines in breeding programmes.

Key Words: Benin, *Callosobruchus maculatus*, cowpea, Dobie susceptibility index, pest tolerance, resistance

RÉSUMÉ

Le niébé (*Vigna unguiculata* L.) est fortement attaqué par les bruches du niébé (*Callosobruchus maculatus* F.) causant 95% de dégâts. L'usage des plantes résistantes constitue une alternative aux produits chimiques. Ainsi, au Bénin, en absence d'études antérieures sur la résistance du niébé aux bruches les accessions susceptibles sont toujours cultivées. L'objectif général de cette étude est l'évaluation de la résistance des différentes accessions de niébé cultivé au Bénin. En effet, 174 accessions de niébé ont été évaluées en stock. Plusieurs paramètres ont été déterminés : poids initial et final des graines; pourcentage d'insecte émergé; pourcentage de perte de poids, de graines endommagées et de tolérance des insectes; période médiane de développement; indice de susceptibilité de Dobie; indice de croissance; nombre moyen de trous, nombre moyen d'œufs pondus. Les données collectées ont été soumises à ANOVA One-way, corrélation de Pearson et à une régression linéaire multiple. Quatorze accessions étaient résistantes aux bruches à savoir : IT06K-123-1, ALEGI*SECOW3B, IT86D-1038, WC35B, IT86D-1033, TOUMKALAM, KPLOBEROUGE, WC66*NE50, IT06K-270, IT84S-2246-4, WC36, TVU1471, TVU-1367-7 et WC66*5T respectivement avec la susceptibilité de Dobie: 2.96, 2.71, 2.67, 2.58, 2.55, 2.49, 2.46, 2.36, 2.11, 1.42, 1.15, 0.53, 0.00 et 0.00. La corrélation de Pearson montre que pourcentage de graine endommagée, nombres d'insectes émergés, la perte de poids et l'indice de susceptibilité de Dobie sont les paramètres à prendre en compte dans un processus de sélection des accessions résistantes aux bruches. En conséquence, les accessions résistantes observées dans ce travail peuvent être utilisées dans des programmes d'amélioration.

Mots Clés: Bénin, *Callosobruchus maculatus,* niébé, indice de susceptibilité de Dobie, tolérance des insectes, résistance

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp] is an important food crop in sub-Saharan Africa and many other parts of the world (Gupta and Gopalakrishna, 2010). It is well-known as a major source of quality protein in the world, used for food and feed (Obembe, 2008; Timko and Singh, 2008; Dube and Fanadzo, 2013). Cowpea dry grain is used in many different food preparations and its nutrients concentrations range from 21 to 33% protein, 1.8% fat, 60.3% carbohydrate and is a rich source of iron and calcium (Majnoon, 2008; Ddamulira *et al.*, 2015; Abudulai *et al.*, 2016). As a legume crop, cowpea fixes nitrogen, and therefore, contributes to soil improvement, making it better crop to grow in N deficient soils (Marandu *et al.*, 2010).

In addition to the field constraints encountered by the cowpea industry, cowpea is liable to bruchid (*Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae)) attack, which occur in both field and storage. This causes reduction in grain quality and quantity, viability and market value of the cowpea seeds (Emeasor and Emosairue, 2002), reaching up to 95% loss (Carlos, 2000; Ojumoola and Adesiyun, 2014). As a solution, farmers and traders use chemical control, which has harmful effects such as sudden death, blindness and skin irritation on end users (Magaji *et al.*, 2005). In addition, the use of chemical insecticides leads to the development of resistant strains and environmental hazards (Thiaw and Sembène, 2010).

Research trend regard the development of resistant cowpea cultivars as one of the most cost effective and sustainable options to control insect pests in cowpea Boukar *et al.* (2018), this holds true for the control of storage bruchid. Between 30 and 80% of total cowpea production valued over US$ 300 million, which is annually lost due to *C. maculatus* infestation (Ohiagu, 1985).

Several studies have been conducted to assess the resistance of cowpea genotypes to *C. maculatus* (Singh *et al.*, 1985; Singh and

Singh, 1990; Shade *et al.*, 1996). In 2003, researchers at the International Institute for Tropical Agriculture (IITA) in Nigeria screened 8000 cowpea lines and found only three (TVu-2027, TVu 11952 and TVu 11953) to be resistant to *C. maculatus* (Appleby and Credland, 2003). The resistant lines exhibited decreased survival and increased developmental times for *C. maculatus*. One of these bruchid resistant lines, TVu 2027, was used to develop improved cultivars such as IT81D-032, IT81D-1064 and IT81D-1045, that show various levels of resistance to bruchid (Keneni *et al.*, 2011).

Given the economic losses caused by bruchid in cowpea industry, developing bruchid resistant cowpea cultivars is imperative. As mentioned in Acquaah (2012), success in the development of pest and disease resistant cultivars heavily depends on the identification of sources of resistance of cowpea to be used as parental lines in the breeding programme. In Benin, such information on resistance to cowpea bruchid is non-existent. The present study aimed at identifying sources of resistance among the cowpea germplasm available in Benin cowpea breeding programme.

MATERIALS AND METHODS

Study area. The study was conducted in the ambient condition (temperature, relative humidity), at the Non-Timber Forest Products and Orphan Crops Species (NTFPs & Orphan Crop) Unit of the Laboratory of Applied Ecology (LEA) in the Faculty of Agronomic Sciences (FSA), University of Abomey-Calavi (UAC) in Benin.

Germplasm. The study was conducted on 174 cowpea accessions, including 52 from Ghana, 45 from Benin, 7 from Ivory-Cost, 14 from Uganda, 47 from IITA Nigeria-Ibadan, 5 from Niger and 4 from Burkina-Faso. The seeds of these accessions were first multiplied to generate sufficient seeds for the screening and further experiments.

Mass rearing of bruchid. Adult bruchid used in this experiment were obtained from infested cowpea grains collected in markets of Benin. These adults bruchid were used to set the cultures in a laboratory room at 27±2 °C and 75±5 relative humidity. Mass rearing cultures of insects were established using a highly susceptible local accession (Tawa), which was kept in a freezer at -20 °C for a week to eliminate other types of infestation (de Castro *et al.*, 2013). One hundred adults bruchid (*C. maculatus*) unsexed were used to infest 12 kg of cowpea.

The experiment was laid in four 3 L plastic jars, sealed with perforated lids to allow maximum aeration and prevent insects escape and other external contamination. At about 72 hr after infestation, the previously introduce one hundred 100 adults were removed and grains were kept incubated until emergence of new adult insects. Upon emergence, the jars' contents were sieved daily to collect 24 hr old insects, which were used in the screening experiment.

Sterilisation of seeds. The disinfestation of cowpea seeds followed the method of de Castro *et al.* (2013), with slight modifications. Cowpea seeds samples used in this experiment were sterilised to kill others pests' larvaes eventually carried from the field, by putting inside bags (three) as hermetic structure and keeping the samples under the freezer for two weeks at -20 °C. This was carried out to discard the seeds from any pest.

Infestation and data collection. The 'resistant' accession, IT84S-2246-4 Singh (1978), and the susceptible local accession Tawa were used as checks during the screening experiment. Ten seeds were randomly sampled from each of the 174 accessions lots. Samples were initially weighed and put into a petri-dish of 90 mm diameter × 15 mm depth. Each sample in petri-dish was infested with newly emerged bruchid at 2:2 sex ratio. Petri dishes were covered with their lids to prevent the insects from escaping.

The experimental units were left till first emergence of bruchid individuals in alpha lattice design, with three replications and 29 blocks per replication, with six accessions per block. Bruchids were allowed to mate and oviposit for 6 days (Ojumoola and Adesiyun, 2014), after which they were removed from the petri-dishes, and the number of dead and alive insects were recorded (Amusa *et al.*, 2013). Thereafter, the numbers of eggs were counted.

Data were collected for 45 days, on number of exit holes, number of damaged and undamaged grains, and residual seed weight. The number of emergence days and percentage pest tolerance were computed using the method of Amusa *et al.* (2014). The percentage of cowpea weight loss was computed as in Kpoviessi *et al.* (2017). Total number of emerged adults from each cowpea accession were counted and recorded daily until three days after no more adult emerged.

Percentage of Bruchid Emerged =

$$\text{Adult emergence (\%)} = \frac{\text{Number of adults emerged}}{\text{Total number of eggs laid}} \times 100$$

(Amusa *et al.*, 2014)

Percentage of seed damaged:

Percentage of seed damaged = % seed damage

$$= \frac{\text{Number of damaged seed}}{\text{Total number of initial seed}} \times 100$$

(Amusa *et al.*, 2014)

Percentages of weight loss (PWL) were calculated as in Kpoviessi *et al.* (2017).

PWL= % weight loss =

$$\frac{\text{Initial weight - final weight}}{\text{Initial weight}} \times 100$$

Percentage of pest tolerance (PPT):

PPT = % Pest tolerance =

$$\frac{\text{Total number of initial seed - number of damaged seed}}{\text{Total number of initial seed}} \times 100$$

(Amusa *et al.*, 2014)

Insect growth index and bruchid resistance rating. Insect growth index (GI) was calculated by using the data on the number of eggs, percentage adult bruchid emergence and the mean development period (Sharma and Thakur, 2014) for each accession using the formula of (Badii *et al.*, 2013):

$$GI = \frac{\text{Percentage adult emergence (\%)}}{\text{MDP}}$$

At the end of the experiment, Dobie Susceptibility Index (DSI) was calculated for each accession using the data recorded on total number of adult bruchid that emerged on each accession and their median development period using the formula of (Dobie, 1974):

$$DSI = \frac{\text{Loge F1} \times 100}{\text{MDP}}$$

Where:

F1 = total number of emerging adults; and
MDP = mean developmental period (days).

The median development period was calculated as the number of days from the middle of oviposition (d3) to the first progeny emergence (Kananji, 2007). In case no insect emerged over the test period, the Dobie Susceptibility Index value was equal to zero (DSI=0) (Kananji, 2007; Msiska *et al.*, 2018).

The susceptibility index ranging from 0 to 11 were used to categorise the cowpea accessions, into categories, namely, 0-3 =

resistant, 4-7 = moderately resistant, 8-10 = susceptible and >10 = highly susceptible (Dobie, 1974).

Data analysis. All analyses were done in R version 3.6.0 statistical software (RCoreTeam, 2019). One-way analysis of variance (ANOVA) was used to examine the differences between the accessions for the resistant parameters recorded. Significant means were separated using Fisher protected Least Significant Differences (LSD) test at 5% significance level. Pearson correlation was used to examine the association among resistance parameters.

RESULTS

Analysis of variance showed significant difference ($P<0.05$) among genotypes for all measured and estimated traits, except for percentage of bruchid emerged (PBE) (Table 1).

Bruchid damage. In this study, the highest initials seeds weight were generated by accessions MALANVILLE, EYIAWO, and AWONLIYIKOUN with 3.20±0.11, 2.40±0.05 and 2.26±0.08 g, respectively; while the lowest weight were by TVU415, N2-CI and TVU-946 with 0.83±0.03, 0.66±0.03 and 0.63±0.06 g, respectively. Cowpea accessions, IT06K-123-1, IT84S-2246-4 and IT06K-270, had the highest final seed weight and accessions; while TVU-946, ELISABETH and N2-CI had lowest final weights. Only four accessions had less than 10% of weight loss, including IT84S-2246-4, TVU1471, WC66*5T and TVU-1367-7. Five cowpea accessions had weight loss greater than 75% including ELISABETH, TOLA, N2-CI, KAKI PETIT GRAIN, and EYIAWO.

The mean number of eggs (<20) were recorded on accessions IT84S-2246-4, TVU1471, IT06K-270, TVU-1367-7 and WC66*5T. Four cowpea accessions had a mean number of eggs higher than 130, namely, MALANVILLE, EYIAWO, PADITUYA and SARC1-91-1 (Table 2).

The number of holes on cowpea seeds varied from 0.00 to 7.66, with the accessions WC66*5T and IT06K-270 having the lowest number of holes, ranging from 90 to103; with the accessions KVX442-3-25SH and MALANVILLE the highest number of holes.

Weight loss of cowpea seeds varied from 0.00 to 10.00 %, with the accessions TVU-1367-7 and WC36 having the lowest weight loss; whereas the accessions ELISABETH, EYIAWO and IT07K-249-1-1 showed percentage seed damage between 80-100%. There was significant difference in the percentage of pest tolerance among accessions. However, the value of 0% of pest tolerance was recorded for 36.21% of the accessions, when TVU-1367-7 and WC66*5T showed 100% of pest tolerance.

For MDP, apart from TVU-1367-7 and WC66*5T with not available (missing) day for median development period, cowpea accessions APAGBAALA, IT07K-309-44, TOUMCIBEKE, ALEGI*SECOW3B and UAM091055-6 (FUAMPEA1) showed a low mean development period (around 22 days); whereas accessions TVU1471, IT84S-2246-4, WC36 and WC35B*SECOW5T showed a high median development period (>30 days).

Accessions showing the Dobie susceptibility index lower than 3, and thereby considered as resistant in this study, represent 8.6% of the germplasm screened. These were IT06K-123-1, ALEGI*SECOW3B, IT86D-1038, WC66*NE50, IT86D-1033, TVU1471, TOUMKALAM, KPLOBEROUGE, WC35B, IT06K-270, IT84S-2246-4, WC36, TVU-1367-7 and WC66*5T.

Pearson correlation analysis. The results of the correlation analysis for seeds parameters are presented in Figure 1. This Figure presents on the diagonal, the distribution of each of the parameters, the scatter plots with the tendency curve below the diagonal and above the diagonal the correlation coefficients with the significant levels. Thus, correlation coefficient of cowpea parameters taken under the infestation of bruchid indicated that weight

TABLE 1. Cowpea seeds and *C. maculatus* parameters analyses for 174 accessions in Benin

Source of variation	df	Parameters										
		ISW	FSW	PWL	NEL	MNH	PSD	PBE	PPT	MDP	GI	DSI
Accessions	173	0.39***	0.21***	779.70*	2539***	1181.10***	1750*	1290^{ns}	1750*	10.65***	2.28*	11.61**
Residuals	348	0.01	0.11	578.90	1308	662.40	1416	1100	1416	5.34	1.84	8.49
Range		0.5-3.4	0-2	0-100	0-197	0-121	0-100	0.00-98.71	0-100	0-41	0.00-4.36	0.00-9.96
CV(%)		25.89	55.75	49.24	57.00	60.49	49.95	49.56	57.23	48.09	51.05	51.18

PBE = Percentage of Bruchid Emergence; ISW = Initial Seed Weight; FSW = Final Seed Weight; PWL = Percentage of Weight Loss; MDP = Median Development Period; GI =The Growth Index DSI = Dobie Susceptibility Index; NEL = Number of Eggs Laid; MNH = Mean Number of Hole; PSD = Percentage of Seed Damage; PPT = Percentage of Pest Tolerance; *** = P<0.001; ** = P<0.01; * = P<0.05; df = degree of freedom

loss had significant and positive correlation with number of eggs laid, percentage of seed damage, Dobie susceptibility index and percentage of pest tolerance. The Number of Eggs Laid had negative correlation with Pest Tolerance, and a positive correlation with the Number of Egg Laid (Fig. 1). A similar trend was observed with the Seed Damage, which had a significant positive correlation with all parameters, except the Pest Tolerance and Final Seed Weight with (Fig. 1). Pest Tolerance had significant negative correlation with parameters: PSD, PWL, NEL, MNH, DSI, GI, and PBE.

The Dobie Susceptibility Index showed a significant high correlation with all parameters, except the Initial Seed Weight (Fig. 1). This Dobie Susceptibility Index had significant positive correlation with Weight Loss, Eggs Laid, Mean Number of Hole, Seed Damage, Bruchid Emergence and Growth Index. It had significant negative correlation with Final Seed Weight, Median Development Period and Pest Tolerance.

DISCUSSION

Cowpea accessions MALANVILLE and DESSERT with the highest initial seed weight (big cowpea seed); ELISABETH and TVU946 with the lowest initial seed weight (small cowpea seed), belonged to the most susceptible to bruchid attack (Table 2). Meanwhile, TVU-1367-7 and WC36 having intermediate grain sizes are the resistant cowpea accessions obtained in the experiment. These findings indicated that grain size did not influence the cowpea accessions resistance to *C. maculatus* attack. This agrees with the results of Amusa *et al.* (2013), who reported that cowpea genotypes (IT99K-494-6 and IT81D-994) showed no significant difference in the grain size, though showed different level of resistance to bruchid infestation. They concluded that grain size did not affect the cowpea genotype resistance to the bruchid attack. Contrary to these authors, some studies (Singh *et al.*, 1974) reported that grain

TABLE 2. Means values of cowpea seeds and *C. maculatus* parameters for 174 accessions in Benin

Names	Cowpea seeds parameters					*C. maculatus* parameters					
	ISW	FSW	PWL	MNH	PSD	NEL	PBE	PPT	MDP	GI	DSI
ACC122W*ALEGI	1.46±0.08	0.50±0.15	66.41±8.77	45.33±14.67	83.33±16.66	58.00±16.09	75.48±11.87	16.67±16.67	28.00±2.08	2.78±0.59	5.83±1.12
ACC122W*NE48	1.30±0.05	0.66±0.21	47.10±19.59	38.33±19.93	66.66±33.33	46.33±23.38	60.88±30.44	33.33±33.33	24.50±0.50	2.49±1.24	4.90±2.45
ACC122W*WC35B	1.36±0.08	0.76±0.27	44.60±18.82	42.00±21.28	66.66±33.33	55.66±28.26	55.78±28.00	33.33±33.33	25.50±1.50	2.20±1.12	4.83±2.42
ACC122W*WC36	0.90±0.05	0.53±0.14	38.14±20.45	23.00±11.93	66.66±33.33	40.66±20.62	52.71±26.48	33.33±33.33	27.00±3.00	1.99±1.04	4.22±2.18
ACC122W*WC66	1.06±0.06	0.43±0.03	59.44±0.55	51.33±2.33	100.00±0.00	80.00±8.54	87.19±3.08	0.00±0.00	24.33±0.88	3.60±0.21	7.59±0.45
ADJAIKUN	1.53±0.03	0.50±0.05	67.50±3.15	62.66±7.83	90.00±10.00	93.00±16.44	90.61±2.93	10.00±10.00	24.67±1.20	3.68±0.14	7.79±0.57
AKOUNADO	1.70±0.05	0.86±0.37	48.72±21.86	53.66±26.90	66.66±33.33	80.66±38.62	61.67±30.84	33.33±33.33	24.50±1.50	2.53±1.27	5.57±2.81
ALEGI*ACC122	1.40±0.05	0.76±0.31	46.54±20.14	35.33±17.67	66.66±33.33	47.00±23.79	59.47±29.75	33.33±33.33	26.00±1.00	2.29±1.15	4.62±2.32
ALEGI*NE48	1.13±0.03	0.60±0.25	46.21±23.33	29.66±14.83	66.66±33.33	54.66±28.34	56.96±28.78	33.33±33.33	26.00±2.00	2.22±1.15	4.76±2.44
ALEGI*SECOW1T	1.23±0.06	0.76±0.26	38.69±19.45	39.00±19.75	66.66±33.33	58.00±28.50	55.49±27.75	33.33±33.33	24.50±0.50	2.27±1.13	5.06±2.53
ALEGI*SECOW2W	1.36±0.03	0.73±0.23	45.42±18.86	36.66±18.36	66.66±33.33	53.66±27.18	57.79±28.97	33.33±33.33	26.00±2.00	2.23±1.12	4.75±2.40
ALEGI*SECOW3B	***1.10±0.11***	***0.80±0.23***	***27.47±18.10***	***17.66±17.66***	***66.66±33.33***	***26.66±26.66***	***25.42±25.42***	***66.67±33.33***	***22.00± NA***	***1.16±1.16***	***2.71±2.71***
ALEGI*SECOW4WA	1.16±0.03	0.66±0.26	43.43±21.73	35.33±17.67	66.66±33.33	49.33±24.99	56.93±28.50	33.33±33.33	24.00±1.00	2.38±1.20	5.00±2.50
ALEGI*SECOW5T	1.50±0.05	0.43±0.03	71.03±2.41	56.66±10.17	100.00±0.00	81.33±14.07	89.54±3.04	0.00±0.00	26.33±2.03	3.44±0.30	7.12±0.63
ALEGI*SS	1.26±0.08	0.73±0.28	44.10±18.49	37.33±18.74	66.66±33.33	54.33±26.69	60.56±30.37	33.33±33.33	24.50±0.50	2.48±1.25	5.08±2.54
ALEGI*WC36	1.16±0.03	0.56±0.27	52.27±22.40	32.33±17.26	66.66±33.33	42.66±22.61	54.49±27.75	33.33±33.33	25.50±1.50	2.16±1.12	4.50±2.31
ANONSIN	1.16±0.03	0.40±0.05	65.40±5.93	59.00±15.14	100.00±0.00	81.33±16.83	91.19±0.49	0.00±0.00	25.33±1.33	3.62±0.19	7.37±0.62
APAGBAALA	1.66±0.03	0.90±0.35	46.44±20.31	56.66±28.80	66.66±33.33	90.00±36.59	60.59±30.30	33.33±33.33	22.50±1.50	2.71±1.36	6.14±3.09
ATAMARIKO	1.26±0.03	0.43±0.03	65.59±3.63	51.00±3.46	96.66±3.33	84.33±5.20	85.97±5.08	3.33±3.33	26.33±0.67	3.27±0.18	7.06±0.16
AWLETCHI	1.36±0.03	0.53±0.03	60.98±2.08	62.00±10.69	96.66±3.33	89.33±13.86	85.96±3.29	3.33±3.33	24.00±1.00	3.58±0.07	7.85±0.48
AWONLIYIKUN	2.26±0.08	1.10±0.35	51.69±14.97	58.33±20.62	93.33±6.66	92.00±26.63	80.72±9.11	6.67±6.67	23.67±0.88	3.43±0.44	7.71±1.03
BLIGOE	0.83±0.03	0.30±0.00	63.88±1.38	45.33±4.84	100.00±0.00	64.00±6.42	84.02±1.55	0.00±0.00	25.33±1.45	3.35±0.25	6.85±0.40
BOUNA-1	1.16±0.08	0.33±0.03	70.64±5.34	51.33±3.28	100.00±0.00	76.66±2.60	86.80±5.89	0.00±0.00	25.00±1.00	3.50±0.36	7.31±0.35
BOUNA-2	0.93±0.03	0.50±0.20	45.55±22.79	26.00±14.46	66.66±33.33	46.00±19.29	53.23±26.79	33.33±33.33	27.00±2.00	1.99±1.02	4.25±2.18
CHAWEKOUN	1.80±0.05	0.63±0.03	64.63±2.95	62.66±4.66	100.00±0.00	107.00±6.42	85.79±1.72	0.00±0.00	24.00±0.58	3.58±0.13	8.18±0.30
DAMANDAMI	1.30±0.05	0.66±0.21	47.10±19.59	39.33±20.49	66.66±33.33	73.66±31.67	51.28±27.23	33.33±33.33	24.50±0.50	2.09±1.10	5.16±2.58
DESSERT	1.66±0.03	1.06±0.06	36.02±3.47	65.66±11.89	80.00±11.54	98.00±15.88	90.13±1.33	20.00±11.55	27.67±2.91	3.32±0.30	7.17±0.90
DEUXTON	1.50±0.05	0.66±0.12	55.59±7.81	63.33±14.26	100.00±0.00	92.66±13.73	86.57±4.50	0.00±0.00	26.33±0.88	3.30±0.27	7.23±0.57
DJETOKO	2.20±0.05	0.73±0.43	66.16±19.68	40.33±18.83	66.66±16.66	62.00±24.63	80.18±8.11	33.33±16.67	27.67±1.20	2.93±0.40	5.95±0.93
EBELATE	1.16±0.03	0.63±0.23	46.21±18.95	35.66±16.95	70.00±30.00	53.33±23.13	64.30±21.15	30.00±30.00	25.33±0.88	2.50±0.80	5.04±1.90
ELISABETH	0.93±0.03	0.16±0.03	81.85±4.07	33.00±4.58	100.00±0.00	50.66±8.17	91.48±2.82	0.00±0.00	24.67±0.88	3.73±0.24	6.75±0.56
EYIAWO	2.40±0.05	0.60±0.15	75.02±6.25	89.00±9.45	100.00±0.00	139.00±9.07	92.33±0.39	0.00±0.00	23.00±0.58	4.02±0.10	9.16±0.11
FARAKO-CI	1.43±0.03	0.60±0.10	57.93±7.57	68.00±7.09	96.66±3.33	96.66±13.22	87.16±1.74	3.33±3.33	27.00±2.00	3.28±0.33	7.21±0.80
FLOWOUIWOUI	1.33±0.08	0.40±0.11	70.17±8.65	68.33±6.96	96.66±3.33	109.33±8.45	88.83±0.90	3.33±3.33	25.67±1.86	3.50±0.26	7.84±0.72
GBOTO	1.20±0.05	0.46±0.03	61.16±1.54	52.66±6.11	100.00±0.00	90.33±2.33	78.98±8.05	0.00±0.00	24.67±1.45	3.24±0.42	7.56±0.55
GLESSISSAFFODO	0.96±0.03	0.60±0.20	38.51±19.30	40.00±20.07	66.66±33.33	68.33±26.67	57.57±28.84	33.33±33.33	25.00±1.00	2.30±1.15	5.11±2.56
H24	0.96±0.06	0.53±0.23	47.47±19.19	30.33±16.79	56.66±29.62	58.33±29.23	45.97±25.46	43.33±29.63	25.50±0.50	1.81±1.02	4.62±2.34

TABLE 2. Contd.

Names	Cowpea seeds parameters					*C. maculatus* parameters					
	ISW	FSW	PWL	MNH	PSD	NEL	PBE	PPT	MDP	GI	DSI
IT00K-1263	1.83±0.03	0.80±0.00	56.33±0.77	76.00±5.19	100.00±0.00	105.00±8.38	88.88±1.17	0.00±0.00	23.67±0.67	3.76±0.09	8.33±0.35
IT06K-108	1.70±0.05	1.00±0.30	39.86±20.32	37.66±20.61	66.66±33.33	56.00±29.14	58.37±29.24	33.33±33.33	25.00±1.00	2.33±1.17	4.96±2.48
IT06K-123-1	***2.00±0.05***	***1.53±0.36***	***22.30±19.85***	***26.33±26.33***	***33.33±33.33***	***42.33±41.33***	***29.60±29.60***	***66.67±33.33***	***23.00± NA***	***1.29±1.29***	***2.96±2.96***
IT06K-135	1.46±0.08	0.53±0.03	63.56±1.57	68.00±3.21	100.00±0.00	103.00±5.03	88.73±1.85	0.00±0.00	26.00±1.00	3.43±0.19	7.57±0.38
IT06K-147-1	1.53±0.03	0.56±0.03	63.05±1.94	58.00±11.23	93.33±6.66	89.66±19.32	81.37±2.67	6.67±6.67	26.33±1.76	3.11±0.21	7.07±0.79
IT06K-242-3	1.63±0.14	0.80±0.25	48.10±20.48	47.33±23.84	66.66±33.33	77.33±33.44	62.18±31.10	33.33±33.33	23.50±1.50	2.66±1.33	5.74±2.89
IT06K-270	***1.60±0.05***	***1.43±0.17***	***10.41±10.41***	***7.66±7.66***	***26.66±26.66***	***13.66±13.66***	***26.83±26.83***	***73.33±26.67***	***24.00± NA***	***1.12±1.12***	***2.11±2.11***
IT06K-91-1	1.56±0.03	0.46±0.08	70.13±5.68	56.00±4.50	100.00±0.00	116.66±6.17	82.35±6.63	0.00±0.00	24.00±0.00	3.43±0.28	8.24±0.13
IT06K-91-11-1	1.63±0.08	1.23±0.37	24.76±22.04	25.33±25.33	33.33±33.33	46.33±46.33	29.02±29.02	66.67±33.33	23.00± NA	1.26±1.26	3.02±3.02
IT07K-188-49	1.23±0.03	0.40±0.00	67.52±0.85	51.00±9.07	90.00±10.00	84.00±10.14	80.38±2.22	10.00±10.00	24.00±1.53	3.39±0.29	7.65±0.55
IT07K211-1-8	1.90±0.05	0.73±0.03	61.42±0.92	88.00±2.64	100.00±0.00	110.00±6.02	90.12±1.71	0.00±0.00	22.67±0.33	3.98±0.02	8.80±0.02
IT07K243-1-10	1.86±0.08	0.96±0.31	46.34±20.32	50.00±25.53	100.00±0.00	76.66±38.48	58.07±29.08	0.00±0.00	23.00±0.00	2.52±1.26	5.80±2.90
IT07K-249-1-1	1.26±0.03	0.46±0.06	63.24±4.75	55.66±2.90	100.00±0.00	82.66±4.97	89.17±0.61	0.00±0.00	23.00±0.58	3.88±0.09	8.12±0.18
IT07K-309-44	1.46±0.06	0.83±0.38	45.23±22.71	48.00±24.02	66.66±33.33	80.00±37.98	57.26±28.63	33.33±33.33	22.50±1.50	2.56±1.29	5.97±3.02
IT07K318-33	1.60±0.11	0.60±0.10	21.61±14.19	56.00±8.66	100.00±0.00	92.00±10.96	88.97±2.72	0.00±0.00	25.00±1.00	3.57±0.15	7.66±0.49
IT2841×BROWN	1.83±0.03	0.53±0.16	71.05±8.93	54.00±2.51	100.00±0.00	84.33±10.03	81.46±2.94	0.00±0.00	25.33±0.88	3.22±0.03	7.24±0.31
IT82K-D-391	1.83±0.08	1.13±0.29	37.24±17.27	39.00±21.00	66.66±33.33	59.00±31.00	63.52±31.78	33.33±33.33	24.50±0.50	2.59±1.30	5.23±2.63
IT83S-742-2	1.13±0.03	0.46±0.03	58.83±2.63	48.00±5.03	100.00±0.00	67.33±4.17	72.54±4.34	0.00±0.00	27.00±0.58	2.70±0.21	6.25±0.23
IT84D-449	1.40±0.05	0.50±0.00	64.16±1.48	76.33±7.44	100.00±0.00	112.66±11.46	76.81±5.51	0.00±0.00	23.33±0.33	3.30±0.27	8.28±0.33
IT84E-124	1.560.03±	0.63±0.08	59.30±6.57	59.66±7.51	100.00±0.00	97.00±12.58	82.83±2.63	0.00±0.00	25.00±1.00	3.33±0.19	7.62±0.51
IT84S-2246-4	***1.60±0.10***	***1.46±0.12***	***8.51±2.42***	***3.00±1.73***	***6.66±3.33***	***20.00±7.09***	***36.72±19.18***	***93.33±3.33***	***37.50±1.50***	***0.65±0.36***	***1.42±0.72***
IT86D-1033	***1.36±0.03***	***1.06±0.18***	***21.61±14.19***	***25.33±25.33***	***33.33±33.33***	***33.00±33.00***	***27.61±27.61***	***66.67±33.33***	***25.00± NA***	***1.10±1.10***	***2.55±2.55***
IT86D-1038	***1.60±0.05***	***1.26±0.38***	***22.22±22.22***	***24.00±24.00***	***33.33±33.33***	***33.00±33.00***	***27.95±27.95***	***66.67±33.33***	***24.00± NA***	***1.16±1.16***	***2.67±2.67***
IT86D-1057	1.63±0.03	0.46±0.03	71.44±1.85	72.33±6.33	100.00±0.00	102.66±6.38	88.32±2.80	0.00±0.00	24.33±1.45	3.67±0.33	8.11±0.64
IT86D-888	1.50±0.05	0.86±0.26	42.10±17.78	44.33±22.21	66.66±33.33	70.66±31.06	56.16±28.08	33.33±33.33	24.50±0.50	2.29±1.15	5.26±2.63
IT87S-1390	1.36±0.03	0.50±0.00	63.36±0.91	77.00±11.01	100.00±0.00	94.00±16.09	84.40±2.92	0.00±0.00	25.67±1.76	3.32±0.27	7.45±0.81
IT89KD-288	1.90±0.00	1.03±0.38	45.61±20.23	59.66±30.33	66.66±33.33	71.00±33.24	64.69±32.35	33.33±33.33	23.00±0.00	2.81±1.41	5.81±2.90
IT90K-76	1.40±0.11	0.96±0.31	33.33±16.66	38.66±19.75	66.66±33.33	58.66±29.47	59.02±29.53	33.33±33.33	24.00±0.00	2.46±1.23	5.25±2.63
IT93K-452-1	1.90±0.11	0.73±0.08	61.46±3.51	75.66±9.38	100.00±0.00	117.00±10.39	88.31±3.17	0.00±0.00	23.00±0.58	3.84±0.04	8.76±0.32
IT97K-449-35	1.83±0.12	0.56±0.03	69.05±0.48	68.00±2.88	100.00±0.00	112.00±4.58	84.73±2.72	0.00±0.00	24.33±0.33	3.48±0.11	8.12±0.13
IT97K-556-6	1.83±0.08	1.36±0.33	23.51±20.80	32.33±32.33	33.33±33.33	44.00±44.00	30.81±30.81	66.67±33.33	23.00± NA	1.34±1.34	3.02±3.02
IT98K-205-8	1.63±0.03	1.13±0.31	31.25±18.04	37.00±21.07	56.66±29.62	54.33±26.44	52.26±26.99	43.33±29.63	26.00±3.00	2.07±1.14	4.68±2.46
IT98K-499-35	1.60±0.05	0.90±0.35	44.87±19.66	61.00±30.80	66.66±33.33	90.33±41.98	62.27±31.16	33.33±33.33	23.50±0.50	2.65±1.32	5.93±2.96
IT99K-499-38	1.70±0.05	0.60±0.00	64.62±1.20	68.33±1.76	100.00±0.00	98.33±7.33	91.18±2.56	0.00±0.00	24.33±1.33	3.78±0.29	8.05±0.34
IT99K-573-1-1	2.00±0.00	1.13±0.38	43.33±19.22	48.33±26.66	66.66±33.33	75.33±26.76	55.11±27.68	33.33±33.33	23.50±0.50	2.35±1.18	5.43±2.74
KAKI	1.56±0.03	0.56±0.03	63.75±2.60	73.00±5.03	100.00±0.00	102.66±3.17	90.04±1.66	0.00±0.00	25.67±1.67	3.54±0.22	7.72±0.47

TABLE 2. Contd.

Names	Cowpea seeds parameters					*C. maculatus* parameters					
	ISW	FSW	PWL	MNH	PSD	NEL	PBE	PPT	MDP	GI	DSI
KAKIGROSGRAIN	1.43±0.06	0.40±0.05	71.62±5.39	72.33±4.33	100.00±0.00	96.66±4.63	90.82±1.61	0.00±0.00	25.00±1.15	3.64±0.12	7.81±0.42
KAKIPETITGRAIN	1.33±0.03	0.53±0.03	75.27±12.38	71.33±4.05	100.00±0.00	93.33±4.17	87.78±1.49	0.00±0.00	26.00±1.00	3.39±0.16	7.37±0.26
KODOBOGBO	1.23±0.06	0.40±0.00	67.36±1.86	59.00±5.50	100.00±0.00	90.66±12.99	79.06±11.30	0.00±0.00	25.67±0.67	3.08±0.43	7.17±0.27
KOMCALLE	1.96±0.06	0.70±0.05	64.16±3.93	80.00±6.80	100.00±0.00	124.00±6.24	90.11±1.39	0.00±0.00	24.00±0.58	3.76±0.12	8.53±0.12
KPEGNIKOUN	1.36±0.06	0.76±0.21	43.07±17.69	50.66±25.86	66.66±33.33	74.66±32.19	59.74±29.92	33.33±33.33	23.50±1.50	2.55±1.28	5.59±2.84
KPLOBE	1.10±0.00	0.36±0.03	66.66±3.03	44.00±2.88	93.33±6.66	66.66±1.45	88.00±5.23	6.67±6.67	27.00±1.00	3.28±0.29	6.57±0.35
KPLOBEROUGE	***1.13±0.03***	***0.83±0.21***	***27.02±18.30***	***18.00±18.00***	***33.33±33.33***	***27.00±27.00***	***28.81±28.81***	***66.67±33.33***	***25.00± NA***	***1.15±1.15***	***2.46±2.46***
KPLOBEWEWE	1.16±0.03	0.70±0.30	39.14±26.35	26.00±23.06	46.66±29.05	39.00±27.30	55.42±28.98	53.33±29.06	28.00±3.00	2.04±1.13	3.81±2.26
KPODJIGUEGUE	1.46±0.03	0.56±0.03	61.42±1.42	78.66±6.66	100.00±0.00	111.00±5.50	87.36±2.66	0.00±0.00	25.00±1.15	3.52±0.26	7.98±0.47
KUMASSI	1.40±0.05	0.53±0.06	62.12±3.64	65.33±7.88	100.00±0.00	93.33±7.21	85.03±5.99	0.00±0.00	24.00±0.58	3.55±0.31	7.91±0.28
KVX442-3-25SH	1.96±0.03	0.70±0.05	64.29±3.51	90.66±10.89	100.00±0.00	128.33±19.09	87.08±2.38	0.00±0.00	23.33±0.33	3.74±0.15	8.74±0.47
KVX61-1	1.30±0.05	0.73±0.08	42.76±9.43	49.00±3.21	100.00±0.00	99.00±11.93	68.30±4.00	0.00±0.00	24.00±0.58	2.85±0.21	7.60±0.16
KVX771-10G	1.76±0.03	0.53±0.12	69.71±6.88	81.33±13.01	100.00±0.00	118.66±12.03	88.07±7.49	0.00±0.00	25.00±1.53	3.58±0.48	8.12±0.64
LAIVI	1.50±0.00	0.60±0.05	60.00±3.84	49.00±5.29	100.00±0.00	99.33±15.45	81.87±3.67	0.00±0.00	24.00±0.58	3.42±0.19	7.93±0.49
MALANVILLE	3.20±0.11	1.26±0.29	60.59±8.78	103.00±10.11	100.00±0.00	171.66±14.43	82.41±0.73	0.00±0.00	24.33±0.88	3.39±0.10	8.84±0.29
MAWUNA	1.56±0.03	0.50±0.10	68.33±5.83	75.33±8.68	100.00±0.00	92.66±0.33	89.94±2.16	0.00±0.00	25.00±2.08	3.66±0.35	7.79±0.64
MOUSSALOCALE	1.30±0.05	0.83±0.23	36.69±17.03	31.66±19.42	60.00±30.55	53.00±30.03	58.58±29.29	40.00±30.55	25.50±0.50	2.30±1.15	4.77±2.42
MU9	1.56±0.23	0.96±0.46	43.33±19.31	41.66±21.86	66.66±33.33	66.66±16.85	62.67±31.34	33.33±33.33	24.50±0.50	2.56±1.28	5.16±2.58
MU9A(ANA)	1.10±0.05	0.43±0.03	60.65±1.56	37.66±5.20	90.00±10.00	68.00±10.01	89.24±3.41	10.00±10.00	25.00±1.53	3.59±0.20	7.15±0.51
N1-TOUBA	0.90±0.05	0.23±0.06	74.72±6.46	46.00±15.39	100.00±0.00	86.66±12.97	71.34±13.63	0.00±0.00	26.33±1.45	2.77±0.61	6.73±0.48
N2-CI	0.66±0.03	0.16±0.03	75.39±3.96	39.66±2.33	96.66±3.33	57.33±5.48	70.33±6.81	3.33±3.33	27.00±0.58	2.61±0.26	5.92±0.21
N3-CI	0.86±0.03	0.40±0.20	51.85±26.70	33.00±16.62	66.66±33.33	48.66±22.84	57.40±28.79	33.33±33.33	26.50±1.50	2.18±1.11	4.52±2.27
NE15*NE48	1.23±0.03	0.63±0.23	48.07±19.88	32.66±16.49	66.66±33.33	56.33±29.92	50.92±26.34	33.33±33.33	25.00±0.00	2.04±1.05	4.79±2.39
NE15*WC10	1.36±0.03	0.53±0.03	60.98±2.08	53.66±0.88	96.66±3.33	93.66±14.81	78.03±8.27	3.33±3.33	25.00±2.00	3.12±0.20	7.49±0.61
NE15*WC35B	1.20±0.05	0.33±0.03	71.85±4.14	48.00±1.52	100.00±0.00	73.33±6.38	89.73±1.38	0.00±0.00	26.00±2.08	3.49±0.25	7.10±0.73
NE15*WC36	1.13±0.03	0.46±0.03	58.83±2.63	60.00±5.85	93.33±6.66	86.00±5.00	89.17±1.28	6.67±6.67	24.00±1.00	3.73±0.15	7.88±0.42
NE21*WC36	1.23±0.08	0.46±0.03	62.08±1.88	55.66±2.66	100.00±0.00	67.66±4.80	92.89±1.63	0.00±0.00	24.67±0.88	3.77±0.13	7.30±0.30
NE48	1.60±0.05	0.81±0.17	51.68±10.41	39.66±17.66	67.33±33.33	55.33±21.40	61.42±25.54	29.67±33.33	21.50±1.50	2.99±1.05	5.33±2.33
NE48*5T	1.26±0.03	0.73±0.28	42.52±21.49	36.00±18.14	66.66±33.33	48.66±24.34	62.10±31.05	33.33±33.33	26.50±1.50	2.35±1.18	4.63±2.33
NE48*NE50	1.00±0.00	0.60±0.20	40.00±20.00	31.00±15.56	66.66±33.33	45.00±21.65	58.81±29.49	33.33±33.33	27.00±3.00	2.20±1.11	4.42±2.26
NE48*SECOW5T	1.20±0.11	0.70±0.35	45.55±22.7	25.00±12.76	66.66±33.33	46.66±25.78	49.83±25.52	33.33±33.33	25.50±2.50	2.00±1.07	4.47±2.25
NE48*WC36	1.13±0.12	0.43±0.03	61.03±4.17	52.66±6.74	100.00±0.00	73.33±11.62	88.12±4.50	0.00±0.00	25.33±1.20	3.50±0.26	7.14±0.50
NE5	1.13±0.14	0.63±0.23	42.32±21.65	35.66±19.02	66.66±33.33	48.33±25.39	60.35±30.18	33.33±33.33	25.50±0.50	2.37±1.18	4.74±2.38
NE50*WC10	1.26±0.03	0.73±0.28	42.73±21.41	37.00±19.46	56.66±29.62	52.33±26.85	57.76±28.88	43.33±29.63	24.00±0.00	2.41±1.20	5.08±2.54
NE50*WC36	1.20±0.05	0.76±0.21	37.41±14.91	23.66±11.86	60.00±30.55	34.00±17.00	54.90±27.82	40.00±30.55	29.00±2.00	1.91±0.99	3.75±1.90
NE51*WC10	1.26±0.03	0.66±0.21	47.64±16.43	45.33±15.70	93.33±6.66	72.33±7.79	71.45±19.63	6.67±6.67	25.00±0.58	2.86±0.79	6.66±0.82
NE51*WC66	1.30±0.05	0.80±0.20	37.88±16.44	34.33±18.02	66.66±33.33	62.66±36.67	39.70±24.78	33.33±33.33	29.00±0.00	1.37±0.85	3.85±1.93

TABLE 2. Contd.

Names	Cowpea seeds parameters					*C. maculatus* parameters					
	ISW	FSW	PWL	MNH	PSD	NEL	PBE	PPT	MDP	GI	DSI
NN-CI	1.20±0.00	0.40±0.00	66.66±0.00	58.33±1.45	100.00±0.00	77.33±1.85	87.45±2.45	0.00±0.00	25.00±0.58	3.50±0.16	7.33±0.24
NONTCHEWAGBEHAMI	1.83±0.03	0.60±0.00	67.25±0.58	79.33±2.18	100.00±0.00	118.00±4.50	81.49±5.52	0.00±0.00	22.67±0.33	3.60±0.28	8.74±0.19
PADITUYA	2.16±0.08	0.73±0.03	66.13±1.02	91.33±2.02	100.00±0.00	139.00±6.65	89.86±0.79	0.00±0.00	25.00±1.15	3.61±0.19	8.42±0.44
PAKAW	1.83±0.12	0.86±0.17	52.28±9.63	45.00±29.56	60.00±20.00	74.66±31.86	75.68±7.57	40.00±20.00	25.67±2.91	3.09±0.65	6.87±1.67
SANZI	1.03±0.03	0.33±0.03	67.57±3.86	56.66±3.84	100.00±0.00	70.66±4.09	89.72±1.32	0.00±0.00	26.33±0.88	3.41±0.09	6.86±0.31
SARC1-91-1	2.03±0.13	0.66±0.03	67.04±1.97	84.33±7.96	100.00±0.00	130.00±13.07	88.42±2.68	0.00±0.00	22.67±0.88	3.90±0.05	9.08±0.18
SECOW19	1.03±0.06	0.60±0.20	42.76±16.99	30.33±15.49	66.66±33.33	54.33±25.47	42.27±23.80	33.33±33.33	24.00±0.00	1.76±0.99	4.65±2.33
SECOW4U	1.10±0.05	0.66±0.16	37.62±18.84	34.33±17.22	66.66±33.33	51.33±26.58	57.08±28.62	33.33±33.33	26.00±1.00	2.20±1.10	4.66±2.35
SECOW4W	1.33±0.06	0.46±0.03	64.68±3.78	61.66±4.05	100.00±0.00	85.00±1.52	88.69±1.73	0.00±0.00	26.33±1.33	3.38±0.15	7.16±0.35
SECOW5T	1.46±0.03	0.70±0.15	51.74±11.74	53.66±16.58	83.33±16.66	77.33±20.26	81.25±7.06	16.67±16.67	25.67±2.33	3.25±0.51	7.06±1.22
SECOW5T*NE51	1.26±0.03	0.76±0.21	39.74±16.36	35.33±18.12	66.66±33.33	57.00±25.00	63.87±22.88	33.33±33.33	27.00±3.06	2.60±1.03	5.39±2.24
SECOW5T*SUNSHINE	1.43±0.03	0.76±0.31	47.46±20.50	32.33±16.29	56.66±29.62	41.33±20.69	58.61±29.31	43.33±29.63	27.50±3.50	2.17±1.11	4.27±2.18
SECOW5T*WC36	1.10±0.00	0.56±0.21	48.48±19.87	32.66±16.42	66.66±33.33	42.33±22.01	58.30±29.29	33.33±33.33	28.00±2.00	2.10±1.08	4.15±2.08
SEWE	1.26±0.06	0.46±0.03	62.69±4.36	57.66±5.78	100.00±0.00	81.66±10.80	83.95±4.46	0.00±0.00	25.00±0.58	3.35±0.10	7.31±0.21
SOHOUNGBLO	1.80±0.05	0.63±0.03	64.84±1.01	67.33±9.73	100.00±0.00	103.00±4.50	86.55±3.94	0.00±0.00	23.67±0.88	3.67±0.20	8.26±0.39
TAWA	1.73±0.03	0.60±0.00	65.35±0.65	69.33±11.46	100.00±0.00	123.33±8.76	88.02±1.31	0.00±0.00	23.33±1.20	3.79±0.21	8.78±0.60
TILIGRE	1.70±0.05	0.60±0.05	64.85±2.20	66.00±15.39	100.00±0.00	86.33±19.93	89.98±1.92	0.00±0.00	25.67±1.20	3.52±0.20	7.33±0.78
TOJOTOHOUN	1.63±0.08	0.50±0.00	69.21±1.62	81.33±8.98	100.00±0.00	125.66±6.98	88.49±0.95	0.00±0.00	26.00±3.06	3.49±0.37	8.06±0.84
TOLA	1.66±0.06	0.36±0.06	77.77±4.55	78.33±4.48	100.00±0.00	92.33±7.31	91.49±3.85	0.00±0.00	24.67±0.88	3.71±0.14	7.81±0.26
TOLAAKOUMIN	2.16±0.17	1.20±0.28	42.62±15.55	14.00±2.88	50.00±10.00	33.66±2.72	75.47±12.77	50.00±10.00	29.33±2.19	2.64±0.57	4.83±0.69
TOLASINMIN	1.76±0.03	0.60±0.05	65.90±3.88	73.33±14.19	100.00±0.00	106.33±22.42	88.76±0.18	0.00±0.00	25.67±1.76	3.49±0.23	7.72±0.86
TONTON	1.76±0.06	0.90±0.35	48.29±21.21	71.33±13.86	100.00±0.00	88.33±10.68	81.14±9.59	0.00±0.00	26.33±0.67	3.10±0.43	7.02±0.56
TOUMCIBEKE	1.63±0.03	0.56±0.12	65.19±7.70	61.33±4.63	90.00±10.00	110.33±13.64	88.63±2.65	10.00±10.00	22.33±0.33	3.97±0.10	8.89±0.34
TOUMKALAM	***1.43±0.03***	***1.16±0.18***	***17.93±14.51***	***12.33±12.33***	***33.33±33.33***	***20.33±20.33***	***28.42±28.42***	***66.67±33.33***	***23.00± NA***	***1.24±1.24***	***2.49±2.49***
TOUMPIPEAKE	1.56±0.03	0.56±0.06	63.88±3.86	55.33±11.05	96.66±3.33	109.00±14.18	89.64±4.29	3.33±3.33	24.00±0.58	3.74±0.23	8.28±0.46
TVU-1	0.96±0.08	0.40±0.00	57.87±4.07	51.66±5.04	90.00±10.00	76.33±6.33	89.96±1.98	10.00±10.00	26.33±0.33	3.42±0.10	6.97±0.23
TVU123	2.13±0.08	0.90±0.05	57.75±2.69	57.33±8.17	93.33±6.66	96.33±0.33	73.99±11.64	6.67±6.67	25.33±1.45	2.91±0.41	7.29±0.32
TVU-1367-7	***1.23±0.03***	***1.23±0.03***	***0.00±0.00***	***0.00±0.00***	***0.00±0.00***	***1.66±1.66***	***0.00±0.00***	***100.00±0.00***	***NA***	***0.00±0.00***	***0.00±0.00***
TVU1471	***1.10±0.05***	***1.03±0.03***	***5.80±2.91***	***1.00±1.00***	***10.00±10.00***	***14.00±6.00***	***17.95±16.06***	***90.00±10.00***	***39.50±1.50***	***0.47±0.42***	***0.53±0.53***
TVU-1509	1.56±0.12	0.90±0.20	40.89±16.92	63.66±13.34	96.66±3.33	87.33±22.51	79.15±7.49	3.33±3.33	23.33±0.33	3.39±0.28	7.75±0.57
TVU15445	1.10±0.05	0.60±0.25	47.32±19.58	33.33±16.70	56.66±29.62	49.00±25.10	55.99±28.97	43.33±29.63	25.50±0.50	2.19±1.12	4.66±2.33
TVU-17263	1.80±0.05	0.70±0.10	61.33±4.38	52.00±13.00	90.00±10.00	72.66±17.33	87.82±2.48	10.00±10.00	26.00±2.08	3.43±0.33	6.99±0.98
TVU415	0.83±0.03	0.53±0.18	37.50±19.09	30.66±15.34	60.00±30.55	49.66±25.70	54.05±27.40	40.00±30.55	25.00±1.00	2.19±1.12	4.73±2.37
TVU-4557	1.23±0.03	0.60±0.25	50.85±21.32	30.00±15.39	56.66±29.62	54.66±28.06	57.67±28.84	43.33±29.63	25.00±0.00	2.31±1.15	4.93±2.47
TVU473	1.73±0.03	0.90±0.40	47.60±23.80	36.66±18.36	66.66±33.33	56.00±28.04	52.49±27.32	33.33±33.33	28.50±1.50	1.83±0.93	4.24±2.13
TVU-801	1.10±0.05	0.63±0.28	44.54±22.34	32.66±16.42	66.66±33.33	44.66±22.33	55.72±27.98	33.33±33.33	29.00±1.00	1.92±0.96	4.02±2.01
TVU-8460	1.40±0.00	0.63±0.13	54.76±9.52	54.33±15.07	96.66±3.33	80.00±19.97	83.66±2.82	3.33±3.33	25.00±2.52	3.43±0.42	7.40±1.19

TABLE 2. Contd.

Names	Cowpea seeds parameters					*C. maculatus* parameters					
	ISW	FSW	PWL	MNH	PSD	NEL	PBE	PPT	MDP	GI	DSI
TVU-8461	1.40±0.05	0.83±0.28	40.17±20.42	41.33±21.45	66.66±33.33	47.00±23.64	59.01±29.53	33.33±33.33	26.50±0.50	2.23±1.11	4.51±2.26
TVU-946	0.63±0.06	0.20±0.00	67.61±3.80	31.00±2.51	100.00±0.00	46.66±4.70	80.46±4.21	0.00±0.00	27.67±0.67	2.91±0.13	5.68±0.26
TZ1GOURGOU	1.90±0.05	0.86±0.08	54.20±5.41	35.66±5.20	93.33±6.66	78.66±13.59	65.25±3.83	6.67±6.67	25.00±0.00	2.61±0.15	6.78±0.26
UAM09-1046-6-2	2.03±0.03	0.73±0.03	63.96±1.03	76.00±16.16	96.66±3.33	120.00±9.00	93.39±1.39	3.33±3.33	23.00±0.58	4.06±0.05	8.91±0.25
UAM091051-1(FUAMPEA2)	1.83±0.08	0.76±0.06	57.72±5.44	44.00±9.29	100.00±0.00	75.00±20.88	84.49±4.63	0.00±0.00	25.33±0.33	3.34±0.19	6.98±0.62
UAM091055-6(FUAMPEA1)	1.63±0.08	0.56±0.03	65.27±1.38	72.66±3.71	100.00±0.00	116.00±2.64	93.60±2.16	0.00±0.00	22.00±0.00	4.25±0.10	9.25±0.09
VIDEGNIKUN	2.16±0.03	1.20±0.40	44.01±19.62	58.66±29.35	66.66±33.33	76.00±37.63	59.60±29.80	33.33±33.33	24.50±1.50	2.44±1.23	5.48±2.76
VITA7	1.43±0.03	0.76±0.26	46.03±19.45	43.66±21.88	66.66±33.33	61.00±30.66	58.07±29.11	33.33±33.33	25.00±1.00	2.32±1.16	5.08±2.55
WC35B	***1.26±0.08***	***0.93±0.23***	***25.92±17.81***	***20.33±20.33***	***33.33±33.33***	***26.33±26.33***	***30.38±30.38***	***66.67±33.33***	***24.00± NA***	***1.27±1.27***	***2.58±2.58***
WC35B*5T	1.16±0.08	0.66±0.16	39.95±20.00	40.00±20.07	66.66±33.33	67.33±33.74	53.36±27.14	33.33±33.33	25.50±0.50	2.10±1.07	4.98±2.50
WC35B*ALEGI	1.00±0.05	0.36±0.06	63.73±4.69	40.66±2.90	100.00±0.00	64.00±15.63	74.66±14.23	0.00±0.00	26.67±1.45	2.76±0.43	6.17±0.35
WC35B*NE48	1.23±0.03	0.73±0.28	41.66±20.97	32.00±16.16	66.66±33.33	48.66±24.76	58.14±29.17	33.33±33.33	24.00±0.00	2.42±1.22	5.00±2.51
WC35B*NE50	1.23±0.08	0.40±0.00	67.24±2.26	59.00±1.52	100.00±0.00	74.66±4.97	88.03±4.61	0.00±0.00	24.33±0.33	3.62±0.19	7.46±0.14
WC35B*SECOW5T	0.90±0.05	0.43±0.13	49.72±18.63	26.66±13.77	63.33±31.79	51.00±27.42	55.53±17.65	36.67±31.80	32.00±4.58	1.86±0.67	4.00±2.01
WC35B*SS	1.13±0.03	0.63±0.18	43.43±17.52	35.66±17.94	66.66±33.33	64.00±32.18	47.52±25.37	33.33±33.33	26.00±0.00	1.83±0.98	4.68±2.34
WC35B*SUNSHINE	1.16±0.06	0.63±0.24	44.75±22.60	35.00±18.52	66.66±33.33	53.33±26.76	58.75±29.38	33.33±33.33	25.00±2.00	2.37±1.19	4.96±2.51
WC36	***1.40±0.05***	***1.23±0.12***	***11.74±8.63***	***3.33±3.33***	***10.00±10.00***	***26.33±18.34***	***8.47±8.47***	***90.00±10.00***	***35.00± NA***	***0.24±0.24***	***1.15±1.15***
WC36*NE50	1.76±0.03	0.53±0.13	69.49±8.27	63.00±11.01	100.00±0.00	104.00±22.30	88.75±1.64	0.00±0.00	26.00±1.73	3.45±0.29	7.59±0.92
WC64	1.06±0.08	0.56±0.21	47.47±19.19	34.00±18.14	66.66±33.33	48.33±24.78	55.97±28.00	33.33±33.33	25.00±1.00	2.24±1.12	4.75±2.37
WC66*5T	***1.10±0.05***	***1.06±0.03***	***2.77±2.77***	***0.00±0.00***	***0.00±0.00***	***0.00±0.00***	***0.00±0.00***	***100.00±0.00***	***NA***	***0.00±0.00***	***0.00±0.00***
WC66*NE48	1.23±0.03	0.43±0.03	64.74±3.28	51.66±6.69	90.00±10.00	78.00±11.78	81.62±4.54	10.00±10.00	25.33±0.88	3.22±0.08	7.10±0.43
WC66*NE50	***1.33±0.03***	***1.06±0.28***	***20.51±20.51***	***18.66±18.66***	***33.33±33.33***	***22.33±22.33***	***29.35±29.35***	***66.67±33.33***	***25.00± NA***	***1.17±1.17***	***2.36±2.36***
WC66*SECOW5T	1.30±0.05	0.63±0.24	49.48±21.15	32.66±16.37	66.66±33.33	57.33±20.73	60.20±30.13	33.33±33.33	24.50±0.50	2.46±1.23	5.03±2.52
WC66*SUNSHINE	1.26±0.08	0.66±0.26	47.58±20.07	30.33±16.79	63.33±31.79	42.33±24.83	55.82±28.30	36.67±31.80	28.50±2.50	1.99±1.04	4.04±2.14
WC68A	1.56±0.14	0.93±0.14	37.51±15.73	31.33±15.83	66.66±33.33	56.33±28.20	53.13±26.83	33.33±33.33	26.50±2.50	2.04±1.06	4.65±2.37
WEWE	1.03±0.06	0.30±0.15	69.36±16.29	47.00±7.00	93.33±6.66	66.66±8.66	86.84±4.98	6.67±6.67	24.67±0.33	3.52±0.16	7.10±0.24
YAWAHARI	1.50±0.05	0.70±0.15	53.76±8.58	57.33±14.49	93.33±6.66	87.66±11.85	84.36±4.18	6.67±6.67	25.00±0.00	3.37±0.17	7.44±0.32
F.pr.	***	***	*	***	*	***	ns	*	***	*	**
LSD (0.05)	0.1867595	0.5495503	38.63837	41.33224	60.41894	58.08886	53.25306	60.41894	16.03518	2.179099	4.679819
CV (%)	25.89	55.75	49.24	60.49	49.95	57.00	49.56	57.23	48.09	51.05	51.18

PBE = Percentage of Bruchid Emergence, ISW = Initial Seed Weight, FSW = Final Seed Weight, PWL = Percentage of Weight Loss, MDP = Median Development Period, GI = Growth Index; DSI = Dobie Susceptibility Index, NEL = Number of Egg Laid, MNH = Mean Number of Hole, PSD = Percentage of Seed Damage PPT = Percentage of Pest Tolerance, NA = Not Available

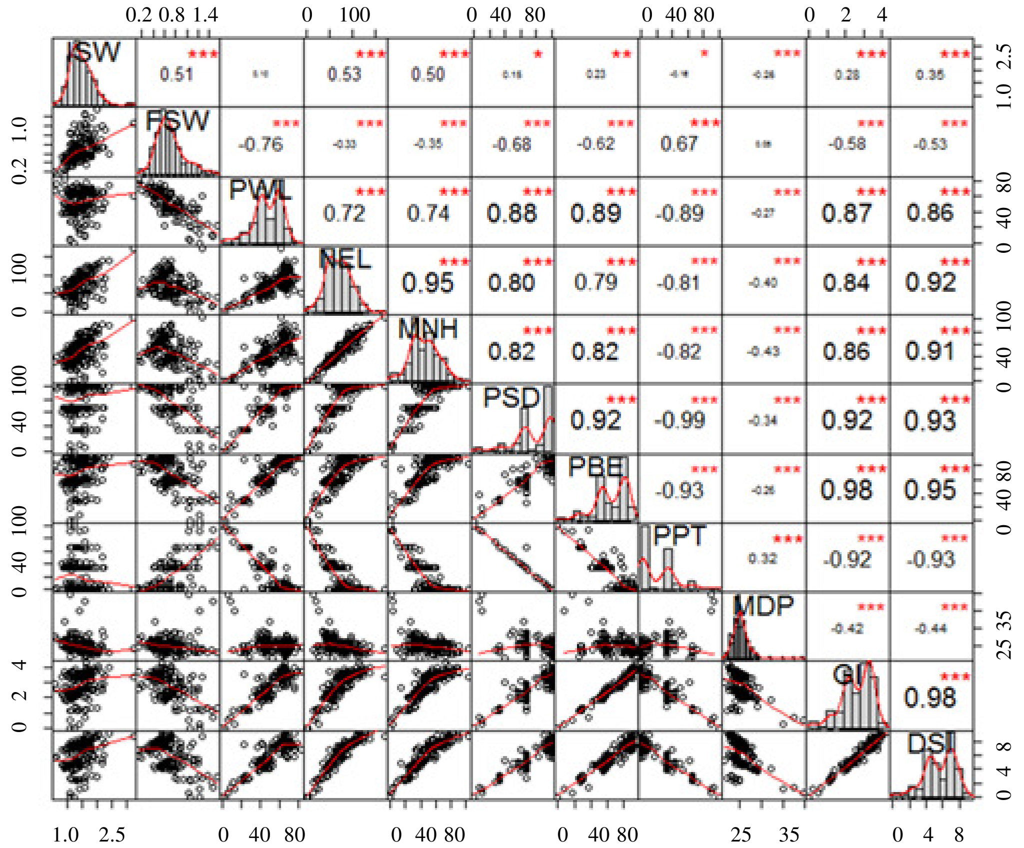

Figure 1. Correlation matrix with scatter plots for 174 accessions in Benin.

PBE = Percentage of Bruchid Emergence; ISW = Initial Seed Weight; FSW = Final Seed Weight; PWL = Percentage of Weight Loss; MDP = Median Development Period; GI = Growth Index; DSI = Dobie Susceptibility Index; NEL =Number of Egg Laid; MNH = Mean Number of Hole; PSD = Percentage of Seed Damage PPT = Percentage of Pest Tolerance; *** = P<0.001; ** = P<0.01; * = P<0.05.

resistance is attributed to variation in grain size and stated that smaller grains offer more resistance to pests attack than the larger grains which supply more food and space for insect growth.

The significant difference in number of eggs laid among the cowpea accessions (Table 1) indicated the existence of variability in the accessions' capacity to affect bruchid oviposition. Thus, these cowpea accessions have different characteristics (physical) that affect the biology of the pest. The study of Lephale *et al.* (2012) explained that the physical barrier may either limit access into the grain or make it unsuitable for oviposition. Subsequently, the barrier may make it difficult for eggs to adhere to the seed, or prevent the larva from penetrating the seed when hatched. Similar studies reported reduction in the rate of oviposition through physical or mechanical characteristics of seeds in some cowpea accession (Messina and Renwick, 1985; Semple, 1992).

This justifies that oviposition on cowpea seeds may not only be due to the antibiotic (chemical) resistance to *C. maculatus* in the seeds. Besides, during the experiment there were some accessions (TVU-1367-7 and

WC66*5T), that were revealed resistance with no hole on the seeds, suggesting that these accessions had some intrinsic characteristics that prevented bruchid penetration into the seeds. Biochemical analysis could reveal the compounds that are responsible for those characteristics in resistant cowpea accessions. Thus, the number of holes is an important variable in the evaluation of cowpea resistance to *C. maculatus*.

Cowpea seed weight loss (Table 2) explained the most damaged cowpea accessions obtained at the end of the experiment. However, the weight loss in the resistant cowpea accessions was null, while in the most susceptible cowpea accessions it was 81.85±4.07%, implying that the growth index and the number of holes in the resistant cowpea accessions were low contrary to those susceptible cowpea accessions. These results could be due to the various insect (larvae) activities inside the seed of cowpea accessions. Similar results were obtained by Jackai and Asante (2003), that variables such as number of holes, as well as weight loss and growth index are the most reliable indicators for cowpea resistance to bruchid. Some studies proved that large grains supply more food and space for insect growth (Singh *et al.*, 1974). This supports the variability in bruchid emergence observed in this experiment, where cowpea accession MALANVILLE, with initial seed weight of (3.20±0.11 g) had more than 142 insects' individuals contrary to TVU-946 cowpea accession (0.63±0.06 g initial seed weight) with about 37 insects' individuals.

The median development period showed variability according to the different cowpea accessions (Table 1). The susceptible cowpea had lower development periods than the resistant ones. The susceptible could be capable of reducing the development period of insect larvae after egg hatching, due to the absence of chemicals components aiming to prevent the bruchid development inside the seed. This difference in median development period between susceptible and resistant cowpea accessions could be related to the absence of physical and biochemical barrier in susceptible cowpea seeds, thus explaining the existence of these biochemical characteristics in resistant seed. These corroborate others findings supporting that the delay in development of *C. maculatus* on the resistant cowpea indicate the difficulty the insect was facing to infest the seeds, due to the presence of anti nutritional or unpalatable compounds. This leads to a longer insect feeding moment to achieve the development stage (Smith and Clement, 2012; de Castro *et al.*, 2013; Miesho *et al.*, 2018).

The variability of pest tolerance among cowpea accessions in the present study showed that the different accessions used contained various physical characteristic and, therefore, the behaviour to the infestation was different. This behaviour displayed by cowpea accessions towards bruchid during infestation was also remarked on the growth index and the Dobie's susceptibility index, so that resistant accessions with high pest tolerance had lower growth index and lower Dobie's susceptibility index too. The pest tolerance obtained with TVU-1367-7 and WC66*5T accessions implied 0.00 growth index and 0.00 Dobie's susceptibility index. These accessions showed the lowest damage from the infestation in terms of number of eggs laid, bruchid emerged, weight loss, number of adult emergence and number of seeds damaged. Contrary to susceptible accessions KVX61-1 and TONTON for example which had 0.00 pest tolerance, with growth index, and Dobie's susceptibility index. Consequently, the susceptible accessions showed highest damaged from the infestation in terms of number of egg laid, weight loss, bruchid emerged, number of adult emerged and number of seeds damaged. Similar results were reported by Mania and Lale (2004) and Maina *et al.* (2006), where TVx 3236 was a susceptible cowpea genotype which showed the least tolerance to bruchid attack, and highest damage from the infestation in terms of number of adult emergence, weight loss and number of seeds damaged.

The significant and positive correlation between weight loss and number of eggs laid, number of holes, seed damaged, adults emerged, growth index and Dobie Susceptibility Index (Fig. 1) suggest that cowpea seed accepting high number of egg led not only to the high number of hole, but also to the high individuals' emerged and high Dobie Susceptibility Index value. This supports that cowpea accession did not tolerate the bruchid infestation. These characteristics could help breeders during cowpea development. Similar correlation results were found in previous studies where cowpea seeds permitting higher number of holes showed higher weight loss and high Dobie's susceptibility value (Shade *et al.*, 1996; Lephale *et al.*, 2012; Miesho *et al.*, 2018). Moreover, the perfect positive correlation between the final seed weight and pest tolerance in this study indicates that the final seed weight could be used as a criterion for ascertaining the resistant status of cowpea accessions.

Amusa *et al.* (2013) showed that the occurrence of a perfect positive correlation between the number of undamaged seeds and pest tolerance indicates that the undamaged seeds may be used as a criterion for improving the resistance of cowpea genotypes. However, these correlations could help breeders in cowpea improvement in terms of bruchid resistance, based on reducing number of holes and eggs laid. The correlation result also showed that seed damage, the number of adult emerged weight loss and Dobie susceptibility index, could be considered essential while selecting bruchid tolerant accessions at the sight of the strong correlation and their higher contributions to the various responses of the cowpea accessions.

CONCLUSION

Among the 174 cowpea accessions used, 8.6% were resistant, 47.7% moderately resistant and 43.7% susceptible. Thus, this study shows the sources of resistance among the cowpea accessions used. The correlation analysis suggest that several parameters, including seed damage, the number of adult emerged, final seed weight, weight loss and Dobie susceptibility index have to be taken into account while selection and breeding of cowpea lines resistant to *C. maculatus*. These resistant accessions obtained in this experiment could serve as sources of resistance to *C. maculatus* in further breeding program.

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