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RESEARCH ARTICLE

Evaluation of cowpea accessions for resistance to flower bud thrips (*Megalurothrips sjostedti*) in Mali

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Abstract

Flower bud thrips (*Megalurothrips sjostedti*) is one of the most damaging pests to cowpea in Africa and varietal resistance is one of the effective approaches to minimize the pest damage. Study was conducted to assess variability among 117 genotypes in addition to two resistant (Sanzisabinli and TVu 1509) and one susceptible (Vita7) checks at Cinzana and N'Tarla locations under natural and artificial infestations of thrips. Parameters such as total number of pods per plant and damage scoring were used to assess the test entries. Genotypes CIPEA82672, Suivita2, TVu 1509 and Sanzisabinli were found highly tolerant, Diaye and TVu7677 moderately tolerant whilst nine genotypes were found tolerant to thrips attacks. CIPEA82672 and Suivita2 had higher grain yield than the resistant checks. Year by genotype, year by location and year by location by genotype interactions were significant for most traits. Genotype by genotype by environment (GGE) effect on yield showed CIPEA82672 most stable across both locations while Suivita2 was only stable at N'Tarla. High broad sense heritability (H2b) was observed for some traits such as damage scoring across locations. Highest genotypic coefficient of variation (GCV) of 81.24 and phenotypic coefficient of variation (PCV) of 75.62 were attributed to total number of pods per plant. Positive correlations were detected between the damage scoring and the number of adult thrips from Cinzana (R^2= 0.264) and N'Tarla (R^2= 0.603) locations. Confirmation of identified cowpea genotypes highly and moderately tolerant to thrips attacks could be used to improve farmers' preferred cowpea genotypes susceptible to thrips.

Key words: Variability, cowpea, Megalurothrips sjostedti, GGE, resistance, damage scoring.

Introduction

Cowpea [*Vigna unguiculata* (L.) Walp.] is an important grain legume for human nutrition over the world. About 90% of the world cowpea is produced in West Africa with 4,525,891 tons of dried grains harvested within an annual area up to 12 million hectares (FAOSTAT, 2014). In terms of grain production Nigeria is the leading country followed by Niger, Burkina Faso and Mali (FAOSTAT, 2014). Based on the last 15 years' FAO data, cowpea production has increased in Mali from 100,126 tons in 2000 to 149,248 tons of grains in 2014, while the harvested area has increased from 258,400 in 2000 to 353,382 hectares in 2014. There were some fluctuations in both parameters due to climatic variations. Cowpea is an important crop particularly in sub-Saharan Africa (SSA) because of its adaptability to the agro system of the sub-region, its high protein content in both grains (23-36 %) and leaves (29-43 %) and use as a cash crop (Walker, 1982; Marconi *et al.*, 1993; Ehlers and Hall, 1997; Boukar *et al.*, 2011). The haulm is used to feed livestock whereas the leaves, peas and pods are consumed by humans. In addition to these usages, cowpea is an important component of the sustainable cropping systems because it improves the soil fertility of marginal lands and ensures ground cover while increasing the soil humidity and suppressing weeds (Inaizumi *et al.*, 1999). Through nitrogen fixation, cowpea cultivation plays an essential role in crop rotation where fertilizers are expensive or not available (Golob *et al.*, 1996). In Mali, cowpea is mainly grown in the Sudan Savanna and Sahel agro-ecological zones. It is the second most important legume grown after groundnut and its demand is estimated to be 23,000 MT/year (Monyo *et al.*, 2013). Cowpea can contribute to food security and poverty alleviation due to its early maturity which occurs in the middle of the rainy season when other crops are still growing. Cowpea has an important market potential. During some periods of the year, the price of the grain gets very high especially in towns that increase the farmers' incomes (Inaizumi *et al.*, 1999).

Despite the importance of cowpea in SSA where it can reasonably yield well under conditions that may not be favorable for some other crops, its production has been facing a lot of biotic and abiotic constraints leading to severe yield losses (Ehlers and Hall, 1997). Among the most important yield limiting factors, insect pests account for up to 80% losses throughout the cowpea cropping areas (Singh, 1990). . Currently, breeding programs focus on developing cultivars with resistance to insects that constitute the most important constraints to cowpea grain production worldwide (Keneni *et al.*, 2011; Okonya and Maass, 2014). One of the most damaging pests of cowpea in field condition is the flower bud thrips (*Megalurothrips sjostedti*) Trybom (Thysanoptera: Thripidae). *M. sjostedti* attacks the cowpea crop at flowering stage and prevents pods production (Ngakou *et al.*, 2008) thereby causing appreciable grain yield reduction. It is widespread and most destructive pest in West Africa, causing 20-80% yield losses (Tamò *et al.*, 1993; Bottenberg *et al.*, 1997; Jackai and Adalla, 1997; Ngakou *et al.*, 2008). With climate change, we can expect that the impact of flower bud thrips in drought-prone regions such as Mali might increase due to climate-driven thrips population outbreaks (Shiferaw *et al.*, 2014).

Variations in planting date, crop rotation and intercropping have been recommended as cultural practices to limit flower bud thrips infestation (Parrella and Lewis, 1997). But these methods are not effective due to variability in the thrips species biology and wide host range including cereals, vegetables and some other legumes (Morse and Hoddle, 2006). Garlic (*Allium sativum*), Ryanodine (*Ryania speciosa*), and Pyrethrum (*Chrysanthemum coccineum*) have been applied for thrips management (Kuepper, 2004). Successive insecticide applications have resulted in reduction of thrips density up to 80% (Jackai and Daoust, 1986; Karungi *et al.,* 2000; Egho, 2011). However, the application of synthetic and non-synthetic insecticides could have negative effects such as rapid development of insecticide resistance in thrips populations resulting in the chemical treatments becoming ineffective with time (Morse and Hoddle, 2006). Therefore, the most promising approach to minimize yield losses linked to thrips damage in cowpea would be to identify lines with tolerance/resistance to the insect. The use of these lines could be integrated with other control methods such as biological control as the basis for integrated pest management (Tamò *et al.*, 2012).

Several studies have been carried out to identify cowpea materials resistant to flower bud thrips. Sanzisabinli, ITH 98-45 and ITH 98-47 and TVu 1509 were reported to have high levels of resistance to flower bud thrips (Abudulai *et al.*, 2006; Omo-Ikerodah *et al.*, 2009). Also IITA (1994) reported a high level of resistance against the cowpea flower bud thrips with the following lines: IT90K-277-2, KVx404-8-1, Moussa Local, Sewe, TVu 1509, TVx3236 and IT91K-180. In certain cases, the tolerance/resistance level of these varieties was insufficient to support severe infestation of thrips as reported by Alabi *et al.* (2003) where some local varieties performed better than the resistant check TVu 1509. Mali is one of the centres of cowpea domestication and there is high genetic variability among *Vigna* species which is composed of wild perennial, wild annual and cultivated species used for consumption (Doumbia *et al.*, 2013). Despite the high genetic variability existing within Mali's cowpea germplasm, limited investigations have been done to determine their level of tolerance/resistance to flower bud thrips. The severity of thrips infestation and that of other cowpea insects are now increasing mostly due to rainfall scarcity in SSA. Hence, there is need to identify sources of resistance to these pests for genetic improvement of varieties that are already being grown by farmers. The objectives of this study were to determine the genetic variability of cowpea accessions for tolerance/resistance to *M. sjostedti* in Mali and identify accessions with good levels of tolerance or resistance to the attacks of the pest.

Material and methods

Field screening was conducted at two sites, Cinzana (05° 57' W; 13°15' N, Sudanian zone) and N'Tarla (05° 42' W; 12° 35' N, Sudanian Guinea zone) Agronomic Research Stations of IER. In addition, a screen house experiment was conducted at Cinzana Agronomic Research Station. Soil from both pots and field was analyzed before the conduct of the experiments. One hundred and twenty (120) cowpea genotypes were screened during two rainy seasons 2014 and 2015 under both natural and artificial infestations. These materials included 115 accessions from Cinzana Agronomic Research Station Gene bank of IER that were primarily collected from some agro-ecological zones of Mali, 4 resistant (Sanzisabinli, NJG115, TVu1509 and TVU864) and 1 susceptible (Vita7) checks from the International Institute of Tropical Agriculture (IITA). The test lines were planted in 2013 rainy season for the quality assurance of their homogeneity.

Field screening

The test lines were evaluated for *M. sjostedti* damage in 20 x 6 Alpha Lattice Design (α-Lattice) plots with 3 replications. Two rows of the susceptible check, Vita7, were planted as spreader rows around the experimental area and also after every five test lines within experimental blocks two weeks before the test lines to build thrips population in the field. The plots were made up of one row of 2 m with an inter-row spacing of 0.75 m and a distance of 0.2 m between hills in a row. Two seeds were sown per hill and slandered agronomic practices were followed. To avoid interference of other major insect pest such as *Aphis craccivora* Koch (Homoptera: aphididae), one application of the Lambda-cyhalothrin (Karate 1.75 EC) was performed a week after planting border rows. Also, Calfos 500 EC (Profenofos) was weekly applied against the mealy bug *Maconellicoccus hirsutus* Green (*Homoptera: Pseudococcidae*) and the pod borer *Maruca vitrata* Fabricius (Lepidoptera: Crambidae) from the podding period till harvest. Border rows were uprooted when most of the plants reached 50% flowering (at least three weeks after establishing the main experiment) and placed within the experimental area. Microscopic observation was done according to Palmer (1987) and Rugman-Jones *et al.,* (2006) to count and identify thrips species collected from experimentatal fields. The same experiment was established with full insecticide controlled for assessing real performance of different cowpea genotypes.

Screen house experiment

Same materials used in the field were planted in the screen house in pots at Cinzana and the trial was replicated twice using Randomized Complete Block Design. Pots were filled three quarters volume with top soil collected from 15 years fallow loamy soil. Screen house was spread with Lambda-cyhalothrin (Karate 1.75 EC) before establishing the experiment; two seeds from each genotype were sown and thinned to one plant two weeks after seedling emergence. Artificial infestation of cowpea plants started 24 days after planting using flowers harvested in the evening from Vita7 (susceptible) in the field. To increase the number of thrips (*Megalurothrips sjostedti*) to be used for artificial infestation, three periods of flower collections were used: early in the morning (6-7 a.m.), afternoon (12-13 p.m.) and evening (4:30-6 p.m.). Genotypes were infested two times using 30 flowers at 10 days interval between infestation periods. In the morning, tap water was used to irrigate pots whenever necessary.

Data collection

Field data collection started 30 days after uprooting the border rows which was based on number of days to achieve 50% flowering (FF) and maturing (MD), number of peduncles per plant (NPLP), number of pods per peduncle (NPPL), total number of pods per plant (TNPP), peduncle length (PL), number of adult thrips (NAT), number of larvae thrips (NLT) and damage scoring. For screen house, the parameters collected included number of peduncles per plant (NPLP), number of pods per peduncle (NPPL), total number of pods per plant (NTPP), peduncle length (PL), damage scoring and number of adult thrips (NAT). Thrips damages were visually scored by 1-9 scale (Jackai and Singh, 1988) (Table 1).

Table 1: Flower bud thrips damage scoring

Scale and damage scoring	Rating appearance
1: Very low susceptibility	No browning/drying (i.e. scaling) of stipules, leaf or flower buds; no bud abscission
3: Low susceptibility	Initiation of browning of stipules, leaf or flower buds; no bud abscission;
5: Intermediate susceptibility	Distinct browning/drying of stipules and leaf or flower buds; some bud abscission
7:High susceptibility	Serious bud abscission accompanied by browning/drying of stipules and buds; non-elongation of peduncles;
9:Very high susceptibility	Very severe bud abscission, heavy browning, drying of stipules and buds; distinct non-elongation of (most or all) peduncles.

For the population count, ten flowers were collected per variety in the field experiment while three flowers were collected per entry in screen house experiment. Flower samples were put inside plastic bottles containing ethanol diluted at 70%. The collected flowers were investigated in laboratory to counting thrips population and to identify thrips species.

Analysis of variance (ANOVA) for all measured parameters from the field was performed using GenStat 12th edition (Payne, 2009) for years over the location and years across locations. Variance components for all parameters under field assessment were computed using the mixed models residual maximum likelihood (REML). The REML analysis of collected data from number of peduncles per plant, number of pods per peduncle and total number pods per plant was estimated from non-control and control field experiments and also the percentage reduction between the two experiments. Singh and Chaudhary (1985) method permitted computing percentage Phenotypic, Genotypic and Environmental Coefficient of Variations. Estimation of broad sense heritability (h^2_b) was done according to Allard (1999) and Burton and Devane (1953) as genotypic variance (V_g) over phenotypic variance (V_p). Principal component biplot was done using the first two principal components. Correlation analysis was performed using data across locations. Pooled data of number of adult thrips and damage scoring were combined to estimate the correlation level from each location across the years. Data collected within the screen house was analyzed using Randomized Complete Block Design (RCBD) model linked to GenStat 12th edition (Payne, 2009).

Results and discussion

The results discussed below are from two contrasting environments (Cinzana and N'Tarla) with regards to agro-ecological zones, soil types and rainfall levels. These climatic differences have certainly played a role in the differences noted in traits characteristics obtained within the two sites.

Genetic variability estimates

High broad sense heritability values were obtained for 50% days to flowering (89%) followed by 50% days to maturing (88%) and total number of pods per plant (87%) whereas lowest broad sense heritability 17% and 25% were attributed to number of adult and larvae thrips, respectively (Table2). Response to selection is more readily achieved in populations expressing more genetic variability, i.e., higher broad sense heritability for a particular trait (Crippa *et al.*, 2009). The low levels of broad sense heritability for numbers of adult and larvae thrips indicate the involvement of environmental factors negatively affecting the population of thrips. Magnitude of phenotypic coefficient variation (PCV) was higher than genotypic coefficient of variation (GCV) for all traits. The opposite was observed for the GCV and environmental coefficient of variation (ECV) with some traits having higher ECV values than GCV. Total number of pods per plant had the highest values for PCV and GCV (81.24 and 75.62, respectively) whilst damage scoring recorded the lowest PCV (13.17) and GCV (11.99). In breeding, GCV is important since its higher magnitude for a trait allows the reliable selection for that trait. Adewale *et al.* (2010) reported a limitation of selection ability for different genotypes if the GCV is small indicating greater proportion of variation coming from environmental effects. Therefore, the highest GCV compared to PCV indicates that the character is more under the influence of genetic rather than environmental components. This study showed that the total variances for plant traits evaluated could rather be explained by more genetic or environmental factors which were in agreement with some previous reports (Damarany, 1994; Omoigui *et al.*, 2006; Nwosu *et al.*, 2014). However, current findings are in contrast with studies conducted by Manggoel *et al.* (2012) and Aliyu *et al.* (2016) who found a greater GCV than ECV. This contrast could be due to sample size and environmental factors since the two previous studies were done in Southern guinea savannah and savannah agro-ecological zones of Nigeria characterized by bimodal rainfall that could negatively affect thrips population dynamics.

Genotype and genotype by environment interactions (GGE) on cowpea accessions under thrips infestation

Combined data of the 12 tolerant genotypes to thrips showed highly significant difference between locations and genotypes, and significant difference with genotype by location interaction based on Bartlett test (Table 3). The GGE interaction analysis revealed two contrasting mega-environments based on the yield of genotypes that showed some level of tolerance to thrips (Figure 1). Genotypes on the left of vertical axis are tolerant or moderately tolerant whilst the highly tolerant genotypes, on the right of vertical axis, differentiated from the others in accordance to their presence on the first (CIPEA82672) and the second (Suivita2) diagrams. GGE interaction effects showed CIPEA82672 as the most stable genotype in both environments since it was closer to the horizontal axis on the first diagram followed by Suivita2 that was more stable at N'Tarla.

Table 2: Means, variance components and broad sense heritability estimates from nine traits under thrips infestation in field conditions across locations

Parameters	Mean	Range	Ơ^2_p	Ơ^2_g	Ơ^2_e	PCV (%)	GCV (%)	ECV (%)	GCV/ PCV	H$^2_{bs}$ (%)
50%FF	56	30- 97	111.66	99.9	35.28	18.87	17.85	10.61	0.95	89
50%MM	76	48-121	107.51	94.87	37.93	13.64	12.82	8.11	0.94	88
NPLP	16	1-49	22.82	9.74	39.25	29.86	19.51	39.19	0.65	43
NPPL	1	0- 4	0.12	0.0585	0.191	34.64	24.19	44.00	0.70	48
TNPP	4	0-29	10.56	9.148	4.228	81.24	75.62	51.50	0.93	87
PL	18	0-78	28.49	20.76	23.19	29.65	25.31	26.78	0.85	73
NAT	87	7-898	2774.67	695	6239	60.55	30.30	90.79	0.50	25
NLT	83	4- 967	2052.67	344	5126	52.18	22.35	86.27	0.43	17
DS	7	3- 9	0.85	0.7043	0.423	13.17	11.99	9.29	0.91	83

Where, DS: damage scoring; **FF:** days to 50% flowering; **MM:** days to 50% maturity; **NAT:** number of adults thrips per plot; **NLT:** number of larvae thrips per plot; **NPPL:** number of pods per peduncle; **NPLP:** number of peduncles per plant; **TNPP:** total number of pods per plant; **PL:** peduncle length; **Ơ^2_e:** environmental variance; **Ơ^2_g:** genotypic variance; **Ơ^2_p:** phenotypic variance; **ECV:** environmental coefficient of variation; **GCV:** genotypic coefficient of variation **PCV:** phenotypic coefficient of variation; **H$^2_{bs}$:** broad sense of heritability.

Table 3: Variation with genotypes interacted by environment

Source of variation	d.f.	Sum of square	Mean square.	v.r.	F pr.
Location	1	302.029	302.029	61.22	<.001
Replication (Location)	4	14.471	3.618	0.73	0.572
Genotype	11	1831.837	166.531	33.75	<.001
Genotype x Location	8	84.267	10.533	2.14	0.044
Residual	69	340.416	4.934		
Total	93	2573.02	27.667		

Genotypes, locations, years and their interaction effects on traits assessed under thrips infestation in field

Cowpea genotypes showed differed responses to thrips infestation. According to Bicer and Sakar (2008), environmental, phenotypic or genotypic factors may be the source of polygenic variation which gives an expression related to magnitude of variability. High variability was registered with means squares of 50% days to flowering and maturing between Cinzana (Table 4) and N'Tarla (Table 5) locations with across years. This difference may be due to soil structure and composition giving some advantages to genotypes at N'Tarla compared to that of Cinzana with more sandy soils. The same phenomenon was observed with traits such as number of peduncles per plant and pods per peduncle. This difference between both sites could be linked to the high magnitude of number adults and larvae thrips since they feed mostly on plant reproductive organs that are likely to negatively affect the percentage of peduncles per plant. On the other hand, the variation observed in the damage scoring and the number of adult thrips at N'Tarla and Cinzana can be related to the agro-ecological zone with more alternative host plants of thrips at N'Tarla. A total thrips adults was not important in number due to the presence of more thrips parasitoids and predators such as *Orisus insidious* and *Formica rufa* (Ant) which could negatively affect thrips population.

Most traits showed significant variability among genotypes with all sources of variation from across location data suggesting the involvement of environmental factors such as rainfall and *M. sjostedti* (adults and larvae) density which changed from year to year and from location to location (Table 6). These results were in agreement with those from Aremu *et al.*, (2015) and Alabi *et al.*, (2003) outlining high variability among genotypes during two years of screening under natural infestation based on characters like ability to produce peduncle, number of adults and larvae of thrips. The high genetic variability among genotypes was observed by Sariah (2010) while evaluating intrinsic and extrinsic factors influencing cowpea traits. There was no significant difference between the damage scoring with year by location by genotype interactions indicating the constant susceptibility of most of the genotypes to thrips attacks. Current study found the presence of two thrips species namely *Frankliniella schultzei* Trybom (Thysanoptera: Thripidae), and *Sericothrips occipitalis* Hood (Thysanoptera: Thripidae) additional to *Megalurothrips sjostedti*. These observations support previous studies (Salifu, 1982; Salifu, 1986; Tamò *et al.*, 1993; Ngakou *et al.*, 2008) pointing out the presence of these species in West and East Africa

Table 4: Mean squares of nine traits assessed at Cinzana for two years under natural thrips infestation

	df	FF	MM	NPLP	NPPL	TNPP	PL	NAT	NL	DS
G	119	395.8***	903.7***	26.2***	37.4***	73.5***	66.23***	2.5***	22***	24.5***
Y	1	154.7***	298.0***	22.4***	1.4^{ns}	0.01^{ns}	246.5***	3*	378.1***	2.9^{ns}
Y x R		0.9^{ns}	0.8^{ns}	0.8^{ns}	1.3^{ns}	0.6^{ns}	2.39^{ns}	1.8^{ns}	0.5^{ns}	1.8***
Y x G	119	3.0***	3***	2***	1^{ns}	1.43*	3.4***	10.6*	4.7***	1.2*

Table 5: Mean squares of nine traits assessed at N'Tarla for two years under natural thrips infestation

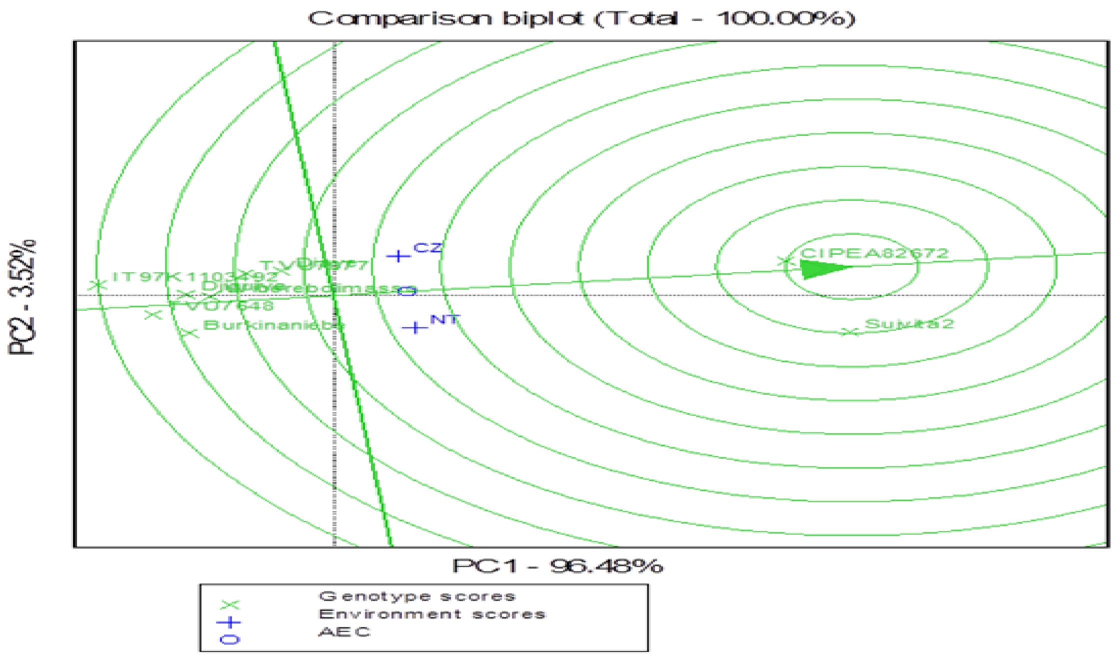
	df	FF	MM	NPLP	NPPL	TNPP	PL	NAT	NL	DS
G	119	880.8***	2191.9***	136.5***	48.1***	73.4***	62.2***	10.9***	8.8***	438.5***
Y	1	45.4***	118.7***	3.9^{ns}	11*	112.6***	126.8***	240.6***	186.4***	46.1***
Y x R	4	3.0*	2.2^{ns}	1.8^{ns}	1.3^{ns}	3.5^{ns}	3.6*	1.3^{ns}	4.6*	1.3^{ns}
Y x G	119	2.9***	3.5***	2***	0.8^{ns}	3.2***	2.8***	3.6***	3.4***	1^{ns}

Table 6: Mean squares of nine traits across locations for two years under natural thrips infestation

	df	FF	MM	NPLP	NPPL	TNPP	PL	NAT	NLT	DS
G	119	718.3***	2180.3***	82.4***	64.3***	122.3***	54.9***	16.21***	7.1***	1087.7***
L	1	11.9***	6.7*	17.9***	102.6***	231.7***	0.01^{ns}	32.16***	13.3***	49.6***
Y	1	125.3***	356.9***	29.8***	6.2*	24.5***	123.1***	288.87***	102.8***	30.8***
L x G	119	2.2***	2.54***	4***	0.7^{ns}	2.8***	2.3***	4.5***	3.1***	1.6***
Y x G	119	3.4***	3.9***	2.3***	1.2^{ns}	2.2***	3.6***	4.43***	4.2***	1.6***
Y x L	1	26.9***	66.1***	16.3***	0.6^{ns}	24***	4.5*	25.44***	6.2*	28.1***
Y x L x G	119	2.5***	2.5***	1.8***	0.7^{ns}	2***	2.4***	5.58***	3.3***	1.1^{ns}

Where, *, **, *** and **ns**: significant at $p < 0.05$, significant at $p < 0.01$, highly significant at $p < 0.001$ and not significant, respectively; **df**: degree of freedom; **DS**: damage scoring; **FF**: days to 50% flowering; **G**: genotype; **MM**: days to 50% maturity; **NPPL**: number of pods per peduncle; **NPLP**: number of peduncles per plant; **TNPP**: total number of pods per plant, **NAT**: number of adults thrips per plot; **NLT**: number of larvae thrips per plot; **PL**: peduncle length; **G**: Genotype; **L**: Location, R: replication; **Y**:year.

Fig1: Genotype by genotype by environment effect on yield



Performance of genotypes under conditions with insecticide versus non-insecticide

Data from control with insecticide and none control plots on open fields demonstrated the degree of thrips damage on different genotypes. Reduction in different yield components assessed was up to 50% for the majority of the genotypes (Table 7). The varieties evaluated were classified into 4 groups with highly tolerant having 3 as damage scoring and composed of Suivita2 and CIPEA82672 in addition to two resistant checks, Sanzisabinli and TVu 1509. Diaye (4.03) and TVu7677 (4.41) were classified as moderately tolerant whilst Burkina niébé, Djiguiya (IT97K-499-35), IT82E-32, IT97K-11034-92, Makurudibi, TVu7648, TVu7710 and Wiberebolimasso were classified as tolerant with scoring scale varying between 5.00 and 5.41. Hence, the clear cut categorization can be understood.

The highest number of pods per peduncle was 3 (CIPEA82672 and TVu 1509) followed by 2 for two highly tolerant and two moderately tolerant varieties. Percentage reduction for total number of pods per plant between infested and control treatments was 99% (TVu7608 and TVu90012) for susceptible genotypes and it ranged from 34% (TVu 1509) to 61% (TVu7677) for the genotypes possessing high and moderate tolerance levels, respective. Most susceptible varieties had 3 pods per plant under infested while highly tolerant varieties recorded 19 (TVu1509), 18 (CIPEA82672 and Suivita2) and 15 (Sanzisabinli) pods per plant. The findings from this investigation were in agreement with those from Alabi *et al.,* (2003), Abudulai *et al.,* (2006), Richard (2011), and Aremu *et al.,* (2015) who selected resistant varieties (Sanzisabinli and TVu 1509) from local varieties based on their higher level of tolerance and lower yield loss percentage from field infestation. However, there was disagreement in term of percentage of yield loss and damage scoring between the current study and that from Omo-Ikerodah *et al.* (2009) who indicated more than 70% yield reduction with Sanzisabinli and TVu 1509 with respectively 4.25 and 5.60 as mean damage ratings. The difference among this previous study and current one may be linked to some parasitoids (*Ceranusis menes* or *Ceranusis fumeratus*) present in Ghana and Nigeria which could have decreased thrips populations allowing some plants to escape from thrips pressure.

Performance of genotypes under artificial thrips infestation in screen house condition

Variability was observed for different traits during artificial infestation and also from year to year (Table 8). Moreover, IT97K-11034-92 was identified with tolerant level to thrips attack in addition to varieties selected in 2014. Genotypes Amary shô had scored the fewest pods per plant during both years while the most was yielded with CIPEA82672. The highest level of tolerance was attributed to CIPEA82672 (2.05) and TVu 1509 (2.3) but CIPEA82672 and Suivita2 had more pods than the two resistant checks (TVu 1509 and Sanzisabinli) during both years. Diaye and TVu7677 were classified as tolerant varieties. Coefficient of variation (%CV) was higher for number of pods per peduncle and total number of pods per plant indicating the large dispersion of genotypes under thrips infestation thereon, variability in term of different genotypes' reaction. There was not a good correlation between number of peduncles per plant and total number of pods per plant since some genotypes had higher number of peduncles with few total pods and vice versa. These results confirmed those of Smith *et al.,* (1993) and Alabi *et al.,* (2006 and 2011) who indicated the involvement of some chemical compounds in cowpea resistance to thrips. In accordance with Alabi *et al.,* (2011), cowpea varieties respond to thrips attacks based on reproductive structures since some genotypes produced racemes and got more abortion at flowering stage. The authors identified some phytochemicals (polyphenols, terpenoids, aglycones and flavinols) with racemes, floral buds and flowers which protect genotypes from thrips damages. There was inconsistency since some varieties previously selected as tolerant to thrips attacks from the field were susceptible under artificial infestations. The disparity in these results may be due to the presence of thrips predators *O. insidious* and *F. rufa* identified on the field. It can also due to the rainfall pattern that is likely to decrease the thrips population while allowing some varieties to escape to thrips attack. The same fluctuation was observed by Salifu (1982) during the comparison of both screening methods (natural and artificial) who found artificial infestation could separate extremely susceptible cultivars from potential resistant cultivars.

Table 7: Performance of 120 cowpea varieties under insecticide and non-insecticide control conditions

	Genotypes	NPLP		**D%**	NPPL		**D%**	TNPP		**D%**	**DS**
		NC	***C***		***NC***	***C***		***NC***	***C***		
Highly Tolerant	**CIPEA82672**	20	39	49	3	4	33	18	30	40	3.0
	Sanzisabinli	20	25	22	2	3	33	15	43	66	3.3
	Suivita2	17	36	52	2	3	50	18	35	49	3.2
	TVu 1509	16	19	14	3	3	33	19	29	34	3.1
Moderately Tolerant	**Diaye**	12	16	25	2	3	50	12	28	57	4.0
	TVU7677	12	22	45	2	2	50	11	28	61	4.4
Tolerant	**Burkina niébé**	14	18	22	2	2	50	9	22	59	5.0
	Djiguiya	11	27	59	1	2	50	6	22	72	5.0
	IT82E-32	7	20	65	1	3	33	7	34	79	5.0
	IT97K-11034-92	10	31	68	2	3	33	8	24	67	5.0
	Makurudibi	9	20	54	1	3	66	8	28	71	5.1
	TVU7648	13	20	35	2	3	66	8	45	83	5.1
	TVU7710	25	36	32	1	2	50	7	36	81	5.4
	Wiberebolimasso	8	16	50	1	3	66	7	33	80	5.3
Susceptible	**Amary shô**	11	18	39	1	3	66	3	24	87	7.4
	CIPEA8002	14	27	48	1	3	66	2	32	93	7.0
	CZ11-94-5C	12	24	50	1	3	66	3	43	93	7.3
	M'barawa	6	19	68	1	3	66	4	33	88	6.8
	Vita7	9	27	67	1	3	66	3	54	94	7.4
	S.E	0.19	0.019		0.001	0.53		0.03	11.2		2.0
	Probability	0.19	<0.001		<0.001	0.003		<0.001	<0.001		0.1
	Min.	2	12		1	2		2	18		3.0
	Average	11	28.82		1.02	3		4	52		7.0
	Max.	25	106		2	4		19	226		8.0

Where, D%: decreasing percentage; **DS:** damage scoring; **C:** control; **NC:** non-control; **Max.:** maximum; **Min.:** minimum; **NPPL:** number of pods per peduncle**;** **NPLP:** number of peduncles per plant; **TNPP:** total number of pods per plant

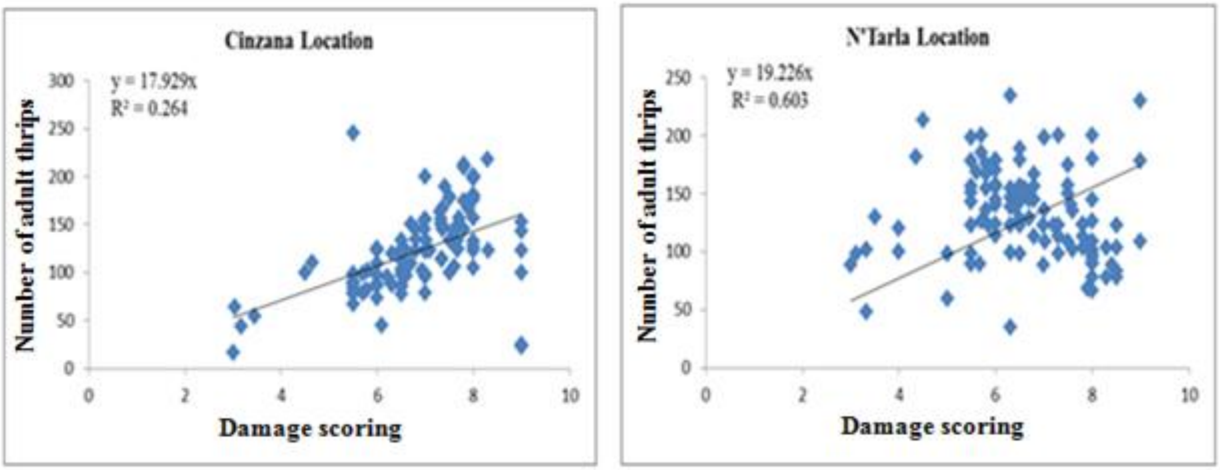
Table 8: Selected genotypes from artificial thrips infestation under screen house conditions

	2014							**2015**				
Genotypes	***NPPL***	***TNPP***	***NPLP***	***PL***	***DS***	***NAT***	***NPPL***	***TNPP***	***NPLP***	***PL***	***DS***	***NAT***
Amary Shô	0	0	8	6	9	22	1	3	12	5	7	15
Burkina niébé	1	2	10	14	7	18	1	5	13	6	6	16
CIPEA82672	**2**	**21**	**16**	**14**	**2.05**	**28**	**3**	**26**	**18**	**15**	**3**	**19**
Diaye	3	8	9	10	5	20	2	8	13	9	5	17
Djiguiya	1	2	11	20	7	17	1	3	14	15	7	14
IT82E-32	1	1	9	11	8	19	1	2	8	8	7	22
IT97K-11034-92							1	3	9	12	7	17
Kalifala	0	0	7	10	9	23	1	2	12	11	7	20
Makurudibi	1	3	8	6	7	16	1	4	9	9	7	13
M’Barawa	1	1	10	8	7	25	1	3	10	5	7	20
Sanzisabinli	**3**	**15**	**15**	**8**	**3**	**16**	**3**	**18**	**17**	**11**	**3**	**20**
Suivita2	**3**	**19**	**17**	**20**	**3**	**25**	**2**	**24**	**15**	**8**	**3**	**14**
TVu1509	**4**	**17**	**13**	**11**	**2.03**	**33**	**3**	**20**	**14**	**15**	**3**	**18**
TVU7648	1	2	7	12	7	30	1	3	11	7	7	13
TVU7677	1	8	9	15	5	17	2	10	10	8	4	16
TVU7710	1	3	9	8	7	23	1	3	10	17	7	15
Vita7	1	2	11	16	7	27	1	2	14	18	7	21
Wiberebolimasso	1	2	10	14	7	19	1	3	13	12	7	12
%CV	50.01	41.15	21.6	24.8	1.51	15.2	49.79	46.34	24.08	37.61	2.15	16.47
SE	0.09	0.28	3.35	2.76	0.13	2.90	0.09	0.41	2.36	3.94	0.18	2.57
S	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.011	<.001	<.001
Average	0.185	1	10	11	9	15	0.185	1	14	13	8	16

Relatedness between damage scoring and thrips population

Current study showed that the screening was carried out in appropriate areas since significance and positive correlations were observed at Cinzana (y= 17.929x; R^2= 0.264) and N'Tarla (y= 19.226x; R^2= 0.603) among thrips damage indices and number of adult thrips. The results show that more than 20% (Cinzana site) and 60% (N'Tarla site) of the difference in damage severity could be related to the number of adult thrips infesting flowers (Figure 2). The difference between areas in term of correlation level could be due to higher presence of thrips alternative hosts that could host thrips during the off-season at N'Tarla. A similar correlation was reported by Alabi *et al.*, (2003) between number of thrips and damage indices during the first (y= 11.01x, R^2= 0.86) and the second (y= 79.09x; R^2= 0.71) year's evaluations with significant difference in terms of R-values from year to year. Salifu (1982) obtained non-significant ($P < 0.05$) positive correlation (y= 0.233 + 0.057x; R^2= 0.81) during field screening about *M. sjostedti*. According to this author, the non-significance of the correlation coefficient is link to the infestations' level and plant susceptibility since the damage scoring was done on some parts of the plant. Moreover, limited correlation was observed by Sariah (2010) between yield and yield stability among accessions studied under natural infestation of *M. sjostedti* and *A. craccivora*. The incoherence between previous screening and current one could be due to study areas since the actual screening was done under two different agro-ecological zones and also under two years since there is variability of insect's population from location to location.

Fig 2: Correlation between damage scoring and thrips adult population across years



Relationships between parameters

Analysis of combined data across locations showed high correlation between some traits (Table 9). Although weak correlation were seen between damage scoring and number of larvae thrips (0.16), high correlation existed between damage scoring and some traits such as number of adult thrips (0.48), 50% days to flowering (0.32) and 50% days to maturing (0.32). However, the converse was observed with higher negative correlation between damage scoring with number of pods produced per peduncle (-0.72) and also total number of pods per plant (-0.86). The level of susceptibility or resistance is based on a damage scoring from the numbers of larvae and adult thrips. Negative correlation between numbers of larvae thrips, number of adult thrips and some traits such total number of pods per plant and number of pods per peduncle could be explained by higher tolerance level of the genotypes which may indicate the higher the yield, the lower the damage scoring from the insect. Strong relationship was seen between number of larva thrips and number of adult thrips (0.52), between total number of pods per plant and number of pods per peduncle (0.67). Our results agree with those from previous studies indicating a negative correlation between thrips' damage rating and cowpea yield components, yield components and also number of larvae and adult thrips (Jackai and Singh, 1988; Alabi *et al.*, 2003; Abudulai *et al.*, 2006; Aremu *et al.*, 2015). Aliyu *et al.*, (2016) reported positive correlation between number of peduncles per plant, number of pods per peduncle and total number of pods per plant.

Table 9: Correlation coefficients of nine parameters across locations

	FF	***MD***	***NAT***	***NPPL***	***TNPP***	***NLT***	***NPLP***	***PL***	***DS***
FF	-								
MD	0.91***	-							
NAT	0.05	-0.01	-						
NPPL	-0.23	-0.21	-0.17	-					
TNPP	-0.31***	-0.30***	-0.18	0.67***	-				
NLT	-0.06	-0.11	0.52***	-0.15	-0.16	-			
NPLP	0.25	0.28	-0.01	0.02	0.10	-0.02	-		
PL	-0.30	-0.33***	0.20	-0.01	-0.02	0.28	-0.11	-	
DS	0.32***	0.32***	0.48***	-0.72***	-0.86***	0.16	-0.07	0.02	-

Where, DS: damage scoring, **FF:** days to 50% days to flowering; **MD:** days to 50% days to maturing; **NTA:** number of adult thrips per plot; **NPPL:** number of pods per peduncle; **TNPP:** total number of pods per plant; **NLT:** number of thrips; **NPLP:** number of peduncles per plant; **PL:** peduncle length

Conclusion

The potential for cowpea resistance to flower bud thrips (*M. sjostedti*) from Malian cowpea collections was assessed. Significant variability was observed among genotypes for important parameters related to thrips resistance during field and screen house experiments. This variability could be exploited for cowpea improvement. More damages were found in location where more thrips population was recorded. Genotypes were classified into four groups with the first as highly tolerant composed of resistant checks (Sanzisabinli and TVu 1509) and two genotypes from Mali collection (CIPEA82672 and Suivita2); CIPEA82672 was more tolerant than the resistant check Sanzisabinli. The second group, moderately tolerant, included varieties Diaye and TVu7677. Genotypes from these first two groups could be used as a source of resistant genes to introgress into Malian local materials that are susceptible to thrips attacks. Moreover, Suivita2 could be used to solve more biotic and abiotic constraints since it has been identified by Huynh *et al.*, (2017) as having tolerance/resistance to drought, *Striga gesnerioides*, foliar thrips and *Macrophomina* disease. The severity of these stresses is linked to the shortage of rainfall. Some traits such as 50% days to flowering and maturing, number of larvae and adult thrips, number of pods per peduncle, total number of pods per plant and damage scoring contributed to the variability between the genotypes. More consideration should be given to these traits while identifying the resistance lines to flower bud thrips attacks. The study found positive correlation between thrips damage scoring and number of adult thrips. Thrips population was higher at N'Tarla than Cinzana.

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