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Response of twelve cowpea genotypes (*Vigna unguiculata* L. Walp) to pest attack pressures under field and controlled environmental conditions of Lomami province, central part of Democratic Republic of Congo

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Abstract
Cowpea (*Vigna unguiculata* (L.) Walp) is a vegetable legumes that is highly susceptible to insect pests. These insect pests cause significant damage to food legumes in the field. In rural areas, yield losses attributable to pests oscillate between 20 and 100% depending on the cropping season, the farming practices and the local environmental characteristics. The assessment of the sensitivity to pest attacks by 12 cowpea genotypes was conducted under field and research station conditions in Ngandajika territory during the long and short rainy seasons of year 2015 and 2016.
The 12 genotypes showed different levels of resistance and sensitivity to insect infestations and attacks under field and controlled environmental conditions. Much as numerically high number of individuals were recorded, no significant (P>0.05) difference in the pest species population density was observed on the different cowpea varieties evaluated. Overall, out of the 12 genotypes evaluated, some (CNGKASB5-2-0-T, CNGKASA2-2-L, CNGKASG1-0-T, Mujilanga) were considered as moderately resistant or tolerant to pest attacks in the Ngandajika territory. These genotypes may be targeted by as reliable sources of resistance during breeding (selection) works aiming at developing cowpea seeds that are tolerance to abiotic and biotic stresses in the Lomami Province.

Keywords: Cowpea genotypes, Assessment, Resistance, Pest attacks, Smart-breeding

1. Introduction

The cowpea (*Vigna unguiculata* (L.) Walp.) Is one of the major legumes grown and consumed in tropical and subtropical areas of Africa, Asia, Europe and America [27]. Worldwide, it is estimated that 6.4 million tons of cowpea are produced annually on about 12.7 million hectares [5]. Indeed, Sub-Saharan Africa contributes with about 95% of world production, of which more than 80% is produced in West Africa [31, 24, 25].

In the Democratic Republic of Congo (DRC), cowpea is grown almost throughout the national territory for its edible seeds. About 149305 ha of land is dedicated to cowpea crop, leading to about 77604 tons [5, 22] each year. Cowpea yield is low at the famer level, average about 450 kg / ha, although the yield is above 2 tons/ha at research station [5].

In D R Congo the need and demand for cowpea grains is high and continue rising; yet current production does meet local demand for domestic consumption. Low yield and production are due to biotic and abiotic constraints. Biotic constraints are particularly associated with high yield loss in D R Congo. Much as diseases are also important, the key biotic constraints are arthropod pests, mainly *Aphis craccivora* Koch (Homoptère: Aphididae),
Maruca vitrata Fabricius (Lepidoptera: Noctuidae), *Megalurothrips sjostedti* Trybon (Thysanoptère: Thripidae); *Clavigralla tomentosicollis* Stal (Hémiptère: Coreidae); *Riptortus dentipes* Fabricius (Hémiptère: Alydidae); *Anoplocnemis curvipes* Fabricius (Hémiptère: Coreidae), *Mylabris senegalensis* Voigts (Coléoptère: Meloidae), *Ootheca mutabilis* Sahlberg (Coleoptera: Chrysomelidae), *Medythia quaterna* Fairmaire (Coleoptera: Chrysomelidae), *Zonocerus variegatus* L., *Schistocerca gregaria* Forsk (Acrididae), *Nezara viridula* Linnaeus (Hemiptera: Pentatomidae), *Ritorpus dentipes* Fabricius (Hemiptera: Alydidae), [11, 13, 14].
Across different sites (environments), yield losses due to cowpea pests are varied. Currently,

yield loss continue rising may be because of the current global warming. On average, yield loss associated with these insect pests oscillate between 27 and 100% [10, 11, 25]. Similar data on yield loss due to pests are reported word wide in major cowpea growing regions [6, 7, 9, 30, 32].

Hence, the need to reduce negative impacts (yield loss) of these insect pest son cowpea. In this regards, several approaches are being promoted worldwide. Among these include, farming systems, agricultural practices, chemical control, biological control, ecological engineering and landscape-habitat manipulations to enhance the delivery of ecosystem services (biological control services), advocating for the establishment of resilient cropping systems, dissemination of resistant varieties(biotic and biotic tolerant genotypes).

Chemical control seems to be the most effective against pests because of its quick action and immediate effects [32]. However, currently, intense use of agrochemicals is not advised since these chemicals are frequently associated with negative environment and health concerns [6]. Hence, the need to search, test and validate other nonpolluting and environmentally-friendly innovative approaches (strategies) for judicious control of cowpea pests. Among these approaches, the utilization of resistant varieties may be associated with several agronomic and environmental benefits. It is likely that to be promoted significantly in the future for the control of crop pests because of my multiple benefits such as obtaining an optimal yield without spraying because of the tolerance (resistance) biotic stress of the genetic materials [2, 3] Obviously, resistant varieties will help in the reduction of cost of production in rural areas [12] where most small-scale farmers are not endowed by sufficient financial resources to cater for pesticides.

In DR Congo, cowpea genetic richness is low because there are only 10 improved varieties registered in the seed catalog and that have been subject to dissemination for wise use in the past years [23]. Previously released varieties in rural areas are currently susceptible to pest attacks in storages and in the fields, according to farmers. The degree of sensitivity of different varieties remain not documented in DR Congo. These days, it appears relevant to collect baseline data and conducting evaluation (tolerance / resistance level) of available varieties, in terms of resistance/ tolerance to insect pests in central DR Congo. Such information may be useful to breeders aiming at developing cowpea varieties that are tolerant to biotic and abiotic stresses. Hence, the aim of this study was to conduct an evaluation of twelve cowpea lines from one of the national genetic resources center (Ngandajika agricultural Research Station) in terms of relative susceptibility to key insect pests under on-farm and on station field conditions.

2. Materials and Methods

2.1 Study area and experimental sites

2.1.1 Study area

The current study was carried out in Ngandajika territory (Lomami Province, Central DRCongo) during two consecutive cropping seasons: season A in year 2015 (September-December) and season B in year 2016 (February-May).

The Koppën climate classification is Aw4 for the study territory. This climate is characterized by a long rainy season (August-May) and by a dry season (June-August). The average daily temperature is of about 25.3°C and the annual rainfall is averaging 1500 mm.

Ngandajika territory is covered by acidic ferralsols soils. These soils are characterized by a collection of sandy clay sediments with heavy clay, red to ocher-red in color and good structure, more often based on an old lateritic slab [25, 26].

2.1.2 Study experimental sites

2.1.2.1 Research Station of Ngandajika

On-station research experiment was conducted at Agronomic Research station of Ngandajika (INERA) of the National Institute for the Study and Agricultural Research (INERA). Ngandajika Research station (6º 45' South Latitude, 23º 57' East longitude with an altitude of 790 m) is administratively located in Ngandajika Territory (Figure-1: the Map of Ngandajika in Lomami Province and DR Congo)

2.1.2.2 Description of the on-farm field sites

On-farm experiments were conducted during the season B at Yamba village and Mpiana village nearby INERA sites. The on-farm field site at Mpiana village (6°36'South latitude and 23°54' East longitude with an altitude of 685 m), about 28 km of INERA. The on farm field site at Yamba village (6°46' South latitude and 24°01'East longitude with an altitude of 700 m) about 11km far away from the Ngandajika research station. This Field station was previously selected by scientists (researchers) from Ngandajika as a point for demonstration and dissemination of technologies (information) susceptible to make change in the behavior and attitudes of producers (farmers).

2.2 Plant material (characteristics of the genotypes used)

Table 1: characteristics of the genotypes used

Genotype	Origine	Grow habit	maturity	Testa Texture	Density cultivation	Rdt/ha
CNGKASC2-1-1-T	RD Congo	determinate	meduim	smooth	high	1200
CNGKASH1-1-M	RD Congo	determinate	meduim	smooth	high	1250
CNGKASB5-2-0-T	RD Congo	determinate	meduim	smooth	high	1100
CNGKASA2-2-L	RD Congo	determinate	meduim	smooth	high	1100
CNGKASC6-1-L	RD Congo	determinate	meduim	smooth	high	1200
CNGKASE2-0-T	RD Congo	determinate	meduim	smooth	high	1000
CNGKASC5-1A-M	RD Congo	determinate	meduim	smooth	high	1300
CNGKASA7-2-M	RD Congo	determinate	meduim	smooth	high	950
CNGKASG1-0-T	RD Congo	determinate	meduim	smooth	high	850
Mujilanga	Tanzanie	determinate	meduim	smooth	high	800
Yamashi	Nigeria	determinate	meduim	smooth	high	800
Diamant	RD Congo	determinate	early	smooth	high	1000

2.3 On-farm and on-station experimental designs

At both on-farm and on-station experiments, the experimental design adopted was a randomized complete block design with three replicates and twelve treatments. Each plot measured 3m x 2.4m. Twelve cowpea genotypes (CNGKASC2-1-1-T, CNGKASC6-1-L, CNGKASE2-0-T, Mujilanga CNGKASC5-1A-M, CNGKASH1-1-M, CNGKASB5-2-0-T, CNGKASA2-2-L, Diamant, Yamashi CNGKASG1-0-T CNGKASA7-2-M) were supplied by the National Institute for Studies and Agricultural Research (Ngandajika station). Sowing was done at the rate of 3 seeds in each hole at a spacing of 60 cm x 20 cm in the plot area. Two weeks after sowing, the wilting followed and it aimed at leaving two plants per pouch only; hence, the plantation was done a density of 83,333 plants/ha. A hand hoe was used for the land preparation. No fertilizers and no plant protection measures against insect pests of cowpea were applied.

2.4 Data collection approaches

Data collection consisted at recording information about entomological activities on cowpea varieties. The focus was on six common insect pest species. Insect population density (number of adult/young stages/ plant) was recorded during growth and yield phases of cowpea.

The visual counting method was performed between 07:00 am when the mobility on plant parts of insects was considered as reduced [16, 19, 17, 20, 21].

Infestation of common cowpea pests is natural due to the presence of these insects in the ecosystems of the Ngandajika production area.

Defoliating insects such as *Ootheca mutabilis*, *Medythia quaterna* and *Oedaleus senegalensis* occur very early in cowpea plots; their population density was determined from 21 days post- sowing up to 45 days. Data collection was s at 7-day intervals, on 20 plants of each plot, between 8h00 am and 10h00 am when insects are less mobile. The sighting method was used as described by Mukendi *et al.* [25].

For the aphid (*Aphis craccivora*), 10 plants were inspected weekly, starting at 26 days post-sowing. Visual counts of aphids was conducted by examining colonies on the underside of the leaves as recommended [28]. Flower moths were counted during the flowering stages. Hence, ten flowers are picked from each varietal plot, starting at 50 days post-sowing. Three samples were taken every 4 days. Collected flowers were kept in alcohol and later stripped. Thrips were counted under binocular under laboratory conditions as recommended [27]. Field count of *Maruca* was done by the opening of the flower or the flower buds of cowpea. Pod sucking bugs were counted during pod maturity, at about 60 to 80 days post-sowing. Overall, the population density of pod borers was assessed by visual observations and count, earlier in the morning hours (7h00 to 12h00), on 20 plants as recommended [1, 15].

The twelve varieties of cowpea were categorized according to the degree of susceptibility of each of them to pest attacks. For each cowpea pest, the grouping was done using the average mean ($\bar{X}$), the standard deviation (SD) from the varietal average ($\bar{X}i$) as recommended [18].

The retransformation data were used for the calculation of $\bar{X}$, $\bar{X}i$ and SD for each parameter. The table-2 shows the scale used to categorize the different varieties.

Table 2: Variety resistance scale

Category of résistance	Scale for résistance
Highly resistant (HR)	$\bar{X}i < \bar{X} - SD$
Resistant (R)	$\bar{X}i > \bar{X} - SD < \bar{X}$
Susceptible (S)	$\bar{X}i > \bar{X} < (\bar{X} + SD)$
Highly susceptible (HS)	$\bar{X}i > (\bar{X} + SD) < (\bar{X} + 2SD)$

2.5 Statistical data analysis

All data collected were subjected to the analysis of variance (ANOVA). The average number, the standard error, standard deviations of pests (*O. mutabilis, A. barium, M. quaterna, A. craccivora*) attacks was calculated for each cowpea variety. Count data was homogenized by applying square root transformation method. In the result section, displayed data is back-transformed. Means separation was conducted by using the method of the smallest significant difference (LSD) at the 5% threshold (P≤5%). All data analyses were conducted using the STATISTIX 8.0 software (2015).

3. Results
3.1 On-station experiment results

Table 3: Population density of insects during long and short rainy seasons at Ngandajika research- station (data is average on years 2015 and 2016)

	Occurrence insects for the long and short rainy season 2015-2016 (x ± se) at INERA						
Génotypes	***A. craccivora***	***O. senegalensis***	***O. mutabilis***	***A. varuim***	***R. dentipes***	***M. vitrata***	***M. quaterna***
CNGKASC2-1-1-T	16.1 ± 2.8 a	10.3 ± 4.4 a	13.3 ± 3.0 a	7.6 ± 2.3 a	6.4 ± 4.1 a	3.4 ± 1.3a	4.1 ± 1.8a
CNGKASH1-1-M	21.0 ± 9.4 a	8.3 ± 2.2 a	10.1 ± 2.3a	4.3 ± 1.2 a	11.6 ± 6.0 a	3.4 ± 0.3a	4.3 ± 2.4a
CNGKASB5-2-0-T	22.2 ± 9.9 a	6.6 ± 1.2 a	6.1 ± 1.9 a	13.3 ± 0.8 a	9.8 ± 5.1 a	5.5 ± 1.7a	3.6 ± 1.6a
CNGKASA2-2-L	16.3 ± 4.7 a	7.1 ± 1.8 a	8.1 ± 2.1 a	5.1 ± 1.2 a	7.9 ± 2.5 a	3.6 ± 0.2a	3.1 ± 1.4a
CNGKASC6-1-L	12.3 ± 2.4 a	9.8 ± 3.7 a	11.3 ± 1.9 a	5.8 ± 2.0 a	4.8 ± 2.7 a	5.0 ± 3.9a	4.6 ± 2.2a
CNGKASE2-0-T	15.0 ± 2.6 a	9.0 ± 4.1 a	13.0 ± 4.8 a	6.1 ± 1.4 a	5.1 ± 1.7 a	3.2 ± 0.1a	4.0 ± 1.9a
CNGKASC5-1A-M	13.1 ± 0.7 a	8.0 ± 2.8a	11.5 ± 4.2 a	7.5 ± 2.0 a	5.3 ± 1.3 a	4.4 ± 0.6a	4.3 ± 2.0a
CNGKASA7-2-M	5.6 ± 1.7 a	6.8 ± 1.4 a	11.3 ± 3.0a	4.8 ± 1.4 a	8.7 ± 4.4 a	4.8 ± 0.3a	2.8 ± 1.3a
CNGKASG1-0-T	16.6 ± 3.3 a	5.6 ± 1.3 a	9.1 ± 1.6 a	8.0 ± 2.1 a	7.4 ± 1.9 a	2.1 ± 0.5a	4.1 ± 1.8a
Mujilanga	9.7 ± 3.9 a	6.1 ± 1.6 a	10.3 ± 1.6 a	6.3 ± 1.6 a	5.8 ± 2.0 a	2.5 ± 0.7a	2.8 ± 1.5a
Yamashi	19.4 ± 7.6 a	6.0 ± 1.0 a	9.8 ± 0.9 a	4.1 ± 0.7 a	5.2 ± 2.1 a	4.0 ± 0.7a	2.8 ± 1.3a
Diamant	11.4 ± 4.3 a	6.6 ± 1.6 a	9.8 ± 1.2 a	7.3 ± 0.9 a	10.2 ± 4.5 a	2.8 ± 0.3 aaaag	6.1 ± 2.7a
P	NS	NS	NS	NS	NS	NS	NS
CV %	19.0	13.2	28.0	34.0	24.4	12.7	15.8

The 12 genotypes had almost similar levels of infestations by insect pests (Table-3) under research station environmental conditions. The average number of individuals counted varied between 5.6 and 22 per leaf for aphids (*A.craccivora*). The highest number (22.2 ± 9.9) of individual aphids was recorded on the variety CNGKASB5-2-0-T while the lowest number (5.6 ± 1.7) was recorded on CNGKASA7-2-M variety. The levels of susceptibility of genotype was less similar since attack pressures were statistically un-significant (P>0.05) among varieties tried. No genotype was is more tolerant (resilient) than the other since they all attracted similar number of individual for each type of pests. In other words, the 12 varieties were attacked similarly by key insect pests (*A. craccivora, O. senegalensis, O. mutabilis, A. varuim, R. dentipes, M. vitrata, M. quaterna)* since the population density of each pest species on each cowpea variety was similar during seasons A and B of year 2005 and 2006 (Table-3).

3.2 On-farm experiment results
The response of the 12 cowpea genotypes to attacks by key insect pests under rural areas environmental conditions are given in Table -4

Table 4: Population density of cowpea pest at three field sites during the rainy and the dry seasons (data is average of year 2005 and year 2006)

		Occurrence (average numbers) of insects during short and rainy seasons of years 2005 & 2006					
SITES	**GENOTYPES**	***A. craccivora***	***O. senegalensis***	***O. mutabilis***	***A. varium***	***R. dentipes***	***M. quaterna***
	CNGKASC2-1-1-T	3.6 ± 1.4 ab	17.3 ± 6.9a	8.3 ± 2.3ab	3.0 ± 0.1a	11.0 ± 8.3 cdefgh	8.3 ± 0.6 ab
	CNGKASH1-1-M	1.0 ± 1.0 b	12 ± 2.5ab	9.0 ± 1.7a	1.6 ± 0.3a	18.3 ± 1.4 abcde	7.0 ± 3.2 abc
	CNGKASB5-2-0-T	1.0 ± 1.0 b	8.6 ± 0.6ab	9.3 ± 1.8a	2.0 ± 1.0a	17.6 ± 8.2 abcde	7.3 ± 0.8 abc
	CNGKASA2-2-L	6.6 ± 4.1 ab	11.0 ± 1.5ab	3.6 ± 1.4ab	6.6 ± 1.4a	13.0 ± 1.1 abcdefg	8.6 ± 0.3 ab
	CNGKASC6-1-L	3.3 ± 1.7 ab	17.3 ± 3.7a	8.6 ± 1.6a	3.3 ± 1.7a	8.3 ± 4.3 efg	9.3 ± 1.8 ab
INERA	CNGKASE2-0-T	4.3 ± 1.4 ab	16.0 ± 6.0ab	4.0 ± 0.5ab	3.3 ± 1.3a	5.3 ± 2.5 fg	8.0 ± 1.7 ab
	CNGKASC5-1A-M	5.6 ± 0.5 ab	13.3 ± 3.5ab	3.6 ± 0.8ab	3.1 ± 1.3a	4.3 ± 2.1 g	8.6 ± 1.4 ab
	CNGKASA7-2-M	4.3 ± 1.7 ab	9.0 ± 2.5ab	6.3 ± 2.4ab	1.6 ± 0.6a	13.0 ± 9.0 abcdefg	7.6 ± 1.2 abc
	CNGKASG1-0-T	7.0 ± 2.0 ab	8.3 ± 1.2 ab	6.0 ± 1.7ab	3.6 ± 0.8a	11.6 ± 0.6 bcdefg	5.0 ± 0.6 c
	Mujilanga	1.3 ± 0.8 b	9.6 ± 0.6 ab	8.0 ± 2.6ab	3.3 ± 1.4a	9.3 ± 2.8 defg	5.6 ± 2.0 bc
	Yamashi	7.0 ± 3.2 ab	8.0 ± 1.0 ab	8.3 ± 1.4ab	2.6 ± 0.6a	8.6 ± 3.3 efg	5.6 ± 2.0 abc
	Diamant	3.0 ± 0.5 b	13.0 ± 1.0ab	7.3 ± 0.6ab	6.0 ± 1.1a	19.3 ± 4.3 abcd	12.3 ± 0.6 a
	CNGKASC2-1-1-T	9.8 ± 2.8 ab	6.0 ± 0.0 ab	9.0 ± 0.57a	3.6 ±1.2 a	11.6± 1.6 bcdefg	11.6 ± 4.3 a
	CNGKASH1-1-M	13.0 ± 4.6 ab	1.6 ± 0.3 b	10.3 ± 1.8a	1.0 ± 0.4a	11.3 ± 0.9 bcdefg	7.6 ± 2.6 qbc
	CNGKASB5-2-0-T	6.2 ± 1.6 ab	2.0 ± 1.0 b	10.3 ± 0.6a	1.0 ± 0.6a	11.3 ± 2.3 bcdefg	11.6± 4.3 ab
	CNGKASA2-2-L	10.5 ±3.0 ab	3.3 ± 1.4 b	10.3 ± 1.4a	6.6 ± 4.1a	11.6 ± 4.7 bcdefg	8.6 ± 4.1 ab
	CNGKASC6-1-L	7.8 ± 1.4 ab	1.6 ± 0.3 b	10.3 ± 1.4a	3.3 ± 1.7a	11.3 ± 2.3 bcdefg	12.6 ± 4.2 a
MPIANA	CNGKASE2-0-T	9.5 ± 1.3 ab	3.3 ± 1.2 ab	9.3 ± 0.80a	4.3 ± 1.4a	15.3 ± 2.6 abcdefg	11.6 ± 0.6 a
	CNGKASC5-1A-M	5.6 ± 1.2 ab	5.3 ± 1.3 ab	11.0 ± 1.5a	3.3 ± 1.3a	11.6 ± 2.9 bcdefg	11.3 ± 3.3 a
	CNGKASA7-2-M	10.6 ± 6.9 ab	1.6 ± 0.6 b	10.3 ± 1.3a	4.3 ± 1.7a	9.3 ± 1.3 defg	8.0 ± 15 ab
	CNGKASG1-0-T	9.5 ± 1.1 ab	3.6 ± 0.8 ab	10.3 ± 0.3a	7.0 ± 2.5a	12.0 ± 3.5 bcdefg	8.6 ± 2.7 ab
	Mujilanga	7.4 ± 1.2 ab	3.3 ± 1.1 ab	9.00 ± 0.5a	3.3 ± 1.4a	10.3 ± 2.6 cdefg	11.3 ± 2.0 a
	Yamashi	12.9 ± 3.7 ab	2.6 ± 0.6 ab	9.3 ± 1.80a	7.0 ± 3.2a	14.6 ± 2.9 abcdefg	12.6 ± 2.6 a
	Diamant	8.8 ± 1.9 ab	6.0 ± 1.1 ab	10.3 ± 1.8a	3.0± 0.5a	17.3 ± 1.3 abcde	12.6 ± 4.4 a
	CNGKASC2-1-1-T	16.4 ± 2.4ab	6.0 ± 2.5 ab			16.6 ± 0.3 abcdef	
	CNGKASH1-1-M	24.7 ± 8.3a	2.3 ± 1.2 ab			21.6 ± 3.4 abc	

	CNGKASB5-2-0-T	11.5 ± 3.3 ab	2.2 ± 0.3 b			20.6 ± 1.8 abcd	
	CNGKASA2-2-L	14.5 ± 3.3 ab	1.6 ± 03 b			22.6 ± 0.6 ab	
	CNGKASC6-1-L	12.3 ± 2.4 ab	1.6 ± 0.8 b			18.6 ± 1.4 abcde	
YAMBA	CNGKASE2-0-T	14.3 ± 3.0 ab	3.0 ± 1.5 ab			19.0 ± 2.0 abcd	
	CNGKASC5-1A-M	9.9 ± 3. ab	5.0 ± 1.1 ab			20.0 ± 1.1 abcde	
	CNGKASA7-2-M	17.0 ± 12.0 ab	2.0 ± 0.5 b			16.3 ± 1.3 abcde	
	CNGKASG1-0-T	11.7 ± 3.7 ab	2.3 ± 1.2 ab			24.6 ± 2.1 a	
	Mujilanga	13.6 ± 2.3 ab	2.3 ± 0.8 ab			17.3 ± 2 abcde	
	Yamashi	18.9± 7.8 ab	3.0 ± 1.0 ab			19.3 ± 2.6 abcde	
	Diamant	14.7 ± 3.5 ab	4.3 ± 2.3ab			17.3 ± 2.6 abcde	
	CV (%) G	51	38	30	37	23.	50
	CV (%) GxS	45	24	15	38	24.3	19
Significance	*P* Genotypes	0.184	0.082	0.173	0.096	0.771	0.312
	P Sites	0.0008	0.002	0.002	0.001	0.0169	0.0001
	P G x S	0.942	0.520	0.040	0.234	0.552	0.603

The analysis of variance indicate no significant (P>0.05) differences among genotypes for the level of infestations. However, there were significant (P<0.05) differences in level of infestation of the different genotypes across the 3 different study sites. There was a significant (P<0.05) variability in the population density of a given pest species across the 12 genotypes. Some varieties were highly infested by a given species than others.

The results of the on-farm experiments revealed significant (P<0.05) in degree of infestation of each genotype by each of pest species (*A. craccivora, O. senegalensis, O. mutabilis, M quaterna, A. barium*) monitored. Practically, the difference in levels of susceptibility of cowpea genotypes to pest attacks were significant more across the three rural sites (environments). Meaning that there was an environmental effect on the level of susceptibility to pest attacks by the different varieties. The fluctuation in individuals recorded per insect species significantly (P<0.05) oscillated across study sites (locations).

3.3 Determination of levels of sensitivity of cowpea genotypes to pests

Table 5: Categorization of genotypes for their sensitivities and tolerance to key cowpea pests

Categories resistance	Insect species		Genotypes
	1 ***Ootheca mutabilis***		
	Scale	Nbre de variété	
	$\bar{X}$= 8.7 et SD=1.7		
(HR)	$\bar{X}i_{<7}$		
(R)	$\bar{X}i_{>7<8.7}$	4	CNGKASB5-2-0-T, CNGKASA2-2-L, CNGKASG1-0-T, Mujilanga
(S)	$\bar{X}i_{>8.7<10.4}$	6	CNGKASH1-1-M, CNGKASE2-0-T, CNGKASC5-1A-M, Diamant, Yamashi, CNGKASA7-2-M
(HS)	$\bar{X}i_{>10.4}$	2	CNGKASC2-1-1-T, CNGKASC6-1-L,
	2 ***Oedaleus senegalensis***		
	Scale	Nbre de variété	
	6.4 et SD= 4.2		
(HR)	$\bar{X}i_{<2.2}$		
(R)	$\bar{X}i_{>2.2<6.4}$		CNGKASB5-2-0-T, CNGKASA2-2-L, CNGKASA7-2-M, Mujilanga, Yamashi, CNGKASG1-0-T
(S)	$\bar{X}i_{>6.4<10.6}$	-	CNGKASC2-1-1-T, CNGKASH1-1-M, CNGKASC6-1-L, Diamant, CNGKASC5-1A-M, CNGKASE2-0-T
(HS)	$\bar{X}i_{>10.6}$	-	
	3 ***Medythia quaterna***		
	Scale		
	$\bar{X}$= 7.3 et SD=3.4.7.		
(HR)	$\bar{X}i_{<3.9}$		
(R)	$\bar{X}i_{>3.9<7.3}$	7	CNGKASC2-1-1-T, CNGKASH1-1-M, CNGKASA2-2-L, Mujilanga, Yamashi, CNGKASG1-0-T, CNGKASA7-2-M
(S)	$\bar{X}i_{>7.3<10.7}$	5	CNGKASB5-2-0-T, CNGKASC6-1-L, CNGKASE2-0-T, Diamant, CNGKASC5-1A-M
(HS)	$\bar{X}i/_{>10.7}$		
	4 ***Apion. Varium***		
	Scale	Nbrede variété	
	$\bar{X}$= 4.6 et SD=1.7		
(HR)	$\bar{X}i_{<2.9}$	1	CNGKASH1-1-M
(R)	$\bar{X}i_{>2.9<4.6}$	3	CNGKASA7-2-M, Mujilanga, Yamashi
(S)	$\bar{X}i_{>4.6<6.3}$	8	CNGKASC2-1-1-T, CNGKASB5-2-0-T, CNGKASA2-2-L, Diamant, CNGKASG1-0, CNGKASC5-1A-M, CNGKASE2-0-T CNGKASC6-1-L
(HS)	$\bar{X}i_{>6.3}$		-

5 ***Aphis craccivora-***			
	Scale		
	X̄= 10.6 et SD=5.3		
(HR)	X̄i < 5.3.3	1	CNGKASC5-1A-M
(R)	X̄i> 5.3<10.6	6	CNGKASC2-1-1-T, CNGKASB5-2-0-T, CNGKASC6-1-L, Diamant, Mujilanga, CNGKASA7-2-M
(S)	X̄i>10.6 <15.9	2	CNGKASE2-0-T, CNGKASG1-0-T
(HS)	X̄i>10.6	3	CNGKASH1-1-M, CNGKASA2-2-L, Yamashi
6 ***Ritorpus dentipes***			
	Scale		
	X̄= 11.6 et SD=5.5		
(HR)	X̄i < 6.1		
(R)	X̄i> 6.1<11.6	5	CNGKASC2-1-1-T, CNGKASC6-1-L, CNGKASE2-0-T, Mujilanga CNGKASC5-1A-M
(S)	X̄i>11.6 <17.1	7	CNGKASH1-1-M, CNGKASB5-2-0-T, CNGKASA2-2-L, Diamant, Yamashi CNGKASG1-0-T CNGKASA7-2-M
(HS)	X̄i>17.1		
7 ***Maruca vitrata***			
	Scale		
	X̄= 1.25 et SD=0.74		
(HR)	X̄i < 0.51		CNGKASC2-1-1-T; CNGKASA2-2-L; CNGKASE2-0-T, Diamant, Mujilanga, CNGKASG1-0-T, CNGKASH1-1-M; CNGKASG1-0; CNGKASH1-1; Diamant; Mujilanga;
(R)	X̄i> 0.51<1.25		CNGKASA7-2-M; CNGKASB5-2-0-T; CNGKASC5-1A-M; CNGKASC6-1-L; Yamashi,
(S)	X̄i>1.25<1.99		
(HS)	X̄i>1.99		

Highly resistant (HR); Resistant (R); Susceptible (S), Highly susceptible (HS), Nomber of insect (Nbre)

The twelve cowpea genotypes were categorized based on a 4-level scale corresponding to the degree of susceptibility to pest infestation through the growing cycle (Table-5). The general equilibrium of infestations on different varieties was calculated based on their seasonal infestation, which varies between 2 to 25 individuals depending on the case of the pest in question.

Regarding the foliage pest *O mutabilis*, 4 varieties (CNGKASB5-2-0-T, CNGKASA2-2-L, CNGKASG1-0-T, Mujilanga) had an infestation level ranging from 7 to 8.7 individuals; these varieties were categorized as resistant to this insect species. About 6 varieties (CNGKASH1-1-M, CNGKASE2-0-T, CNGKASC5-1A-M, Diamond, Mujilanga, CNGKASA7-2-M, CNGKASC2-1-1-T and CNGKASC6-1-L) were considered as sensitive to *O. mutabilis* (Table-5).

Genotypes CNGKASB5-2-0-T, CNGKASA2-2-L, CNGKASA7- 2-M, Mujilanga, Mujilanga, CNGKASG1-0-T were identified as resistant *O. senegalensis*, whereas CNGKASC2-1-1-T, CNGKASH1-1-M, CNGKASC6-1-L, Diamond, CNGKASC5-1A-M and CNGKASE2-0-T genotypes were identified as sensitive genotypes to *O. senegalensis* insect pest.

The genotypes CNGKASC2-1-1-T, CNGKASH1-1-M, CNGKASA2-2-L, Mujilanga, Mujilanga, CNGKASG1-0- and CNGKASA7-2-M showed some kind of resistance to *M. quaterna*, whereas the rest of varieties were considered as susceptible varieties to *M. quaterna.*

However, among the pests of the group of suckers, it was possible to notice the presence of A. *varium*, which according to the level of natural infestation on twelve genotypes, one could group in three categories among which a single variety CNGKASH1-1-M is very resistant, 3 varieties CNGKASA7-2-M, Mujilanga, Mujilanga are in the group of resistant and finally 8 varieties are characterized as being sensitive in front of this insect.

The line CNGKASC5-1A-M was found to very resistant to *A. craccivora*, whereas 6 other genotypes (CNGKASC2-1-1-T, CNGKASB5-2-0-T, CNGKASC6-1-L, Diamant, Mujilanga and CNGKASA7-2-M) were found to be resistant; 2 varieties (CNGKASE2-0-T, CNGKASG1-0-T) were categorized as sensitive, and the varieties (CNGKASH1-1-M, CNGKASA2-2-L, Yamashi) were classed as very sensitive.

Similarly, 5 varieties (CNGKASC2-1-1-T, CNGKASC6-1-L, CNGKASE2-0-T, Mujilanga, and CNGKASC5-1A-M) were recognized as resistant to *A. craccivora*, whereas 7 varieties (CNGKASH1-1-M, CNGKASB5-2-0-T, CNGKASA2-2-L, Diamond, Mujilanga CNGKASG1-0-T, CNGKASA7- 2-M) were categorized as susceptible to infestation by *R. dentipes*.

The genotypes CNGKASC2-1 genotypes; CNGKASA2-2 and CNGKASE2-0 were found to be very resistant; the batch of genotypes CNGKASA7-2, CNGKASB5-2, CNGKASC5-1, CNGKASC6-1 and Yamashi were classified as resistant to *M. vitrata* infestation under field conditions (Table-5).

4. Discussion

In this study, it was observed that cowpea crop was attracting several insect pest species. There is a rich entomological fauna visiting cowpea at different stages of growth and development is also reported elsewhere as key production constraints. The 12 genotypes evaluated in this study revealed different levels of susceptibility to key insect pests (*A. craccivora*, *O. senegalensis*, *O. mutabilis*, *A. varuim*, *R. dentipes*, *M. vitrata*, and *M. quaterna* w) under controlled (research station) and on-farm conditions

Similarly, Kanteh *et al.* [34] reported similar levels of infestations to cowpea in Benin.

It was also found in this study that genotypes expressed different levels of susceptibility to pest attacks. All genotypes tested attracted a high number of insect numbers since the pests were recorded at different development stages on all genotypes. Most genotypes tested were not resistant to local pest species. Also, Mukendi *et al.* [25] already indicated that the varieties Diamant, IT82D889 and Mujilanga were sensitive to attacks and infestation by *O. mutabilis* pest species. On sensitive materials (genotypes), infestations may be associated with high yield loss. The yield loss may be very high under local conditions because the insect pests attacks the foliage (leaf area) and such attacks may directly impacts on the photosynthetic activity of the plant and thereby threatening the crop productivity.

Word wide, some cowpea pests (sucking, biting insects) such as *A. craccivora*, are considered as devastating pests of cowpea across cropping seasons, much as there exist a specific responses of different genotypes to pest attacks [28]. This means most improved genotypes do not have the change of expressing their yield potential in different environments.

Based on field trial results, it seems that some cultivars (genotypes) were promising since their levels of resistance to key insect pests was judged as acceptable. These varieties include CNGKASB5-2-0-T, CNGKASA2-2-L, CNGKASG1-0-T and Mujilanga. Under field conditions, these varieties buffered the devastating pressure against these monitored polyphagous insect species.

The sensitive genotypes (CNGKASH1-1-M, CNGKASE2-0-T, CNGKASC5-1A-M, Diamond genotypes, CNGKASA7-2-M, CNGKASC2-1-1-T, and CNGKASC6-1-L) that were found to be sensitive to highly sensitive to key insect pest species are very much appreciated by consumers and growers. This remain a key challenge to increase the productivity of cowpea crop. Hence, the need to find out other genotypes that embedded with genetic (internal) mechanisms of resisting insect pest attacks. No significant ($P>0.05$) interaction (genotypes x environment) was found in this study. This is an indication with ongoing global environmental change (climate change/ variability), several cowpea genotypes may worsen the drop-down of their degree of resistance to pest attacks in subsequent years in the study areas.

It was also found that pod bugs were prevalent and occurred with high population density in the study area. Varieties such as CNGKASH1-1-M, CNGKASB5-2-0-T, CNGKASA2-2-L, Diamond, Mujilanga CNGKASG1-0-T, and CNGKASA7-2 were found to be highly infested with pod bugs than the rest of the genotypes studied. Karungi *et al*. [14] and Kamara *et al*. [29, 30] reported similar results in Uganda [29],

As it was observed by previous workers [4, 32, 34], there was a variability in responses to pest attacks by the different lines. It is likely that the environment of each study site and the crop planting density influenced the fluctuation by different insect pest species (aphids, pod borers, thrips). In some cases, infestations by these pests were high when other legume crops (beans, groundnut) were grown in the surrounding of cowpea. Overall most genotypes tested were very sensitive to infestations by aphids and pod borers. Also, areas where there was high population density of alternative plant hosts in the field margins or in nearby fields, the population density of the pest species was always high in the cowpea fields.

Some pest species such as locusts and pod borers (*Maruca vitrata*) are known to be seasonal migratory pest species. Such species may migrate for several months searching for new areas well colonized by wild and cultivated legume plant species legumes along aside areas receiving abundant rainfalls on a regular basis [35]. Hence, in areas where groundnuts and cowpeas are often cultivated, migratory pest species occurred throughout the year because the pest species will always make switches between field containing cultivated legume crops (groundnuts, cowpeas) and wild legume host plant species (Fabaceae) available in semi-natural habitats found nearby or in between gardens. [34]. In the Ngandajika territory, the savannah vegetation covering non-cultivated fields is essentially a mixed mosaic vegetation types (*Imperata cylindrica*, *Hyparrhenia* spp, mixed with diverse types of legumes including legume cover crops and some wild shrubs). Most small scale new cowpea crops are opened in the middle of such savannah vegetation types, exposing cowpea crops to attacks by various phytophagous arthropod inhabiting wild vegetation found in the vicinity of gardens. The farming system (opening small scale gardens in middle of large savanna vegetation landscapes) is one of the reasons why cowpea fields are subject to attacks by diverse entomological fauna.

According to Mukendi *et al*. [25], the high prevalence and incidence of diverse legume crop pest species across seasons and locations in Lomami province may be attributed to the fact that cowpea is generally grown along with other susceptible host crops (such as groundnut, soybean, vuandzou) and related wild legumes found in nearby landscapes.

5. Conclusion

The result of the genotype assessment indicated that some of the cowpea varieties evaluated were resistant, suggesting that they may be used as potential parental strains while aiming at breeding for resistance to key pest insects in the region. Other varieties were found to be tolerant, suggesting that despite the insect load, such varieties had the potential for high yield and some kind of internal mechanisms to compensate for insect attacks.

Since cowpea is preferred crop in the region, currently found resistant (tolerant) varieties may be recommended meanwhile. Much as it is common to find farmers mixing varieties (improved and local ones) as strategy to reduce on impacts of pest attacks, it is not recommended to use sensitive varieties in intercrop patterns. Similarly, farmers should make judicious choice for the source of varieties: they should varieties that have been identified by researchers as tolerant. This means there is a need to strengthen participation (collaboration) between farmers and researchers during the process of seed breeding, testing and validation.

It is likely that promoting the combining of several environmentally-friendly farming practices (crop rotation, mixing cereal and legume crops, planting resistant genotypes) may cut-off the population built-up of pest species. Several landscape and habitat manipulations approaches are needed are needed to be found, tested, and disseminated in rural areas in order to cut-off pest accumulation in the fields and its surroundings.

Promoting innovative ecological engineering farming practices may turn into profitable ventures for farmers. Extension workers need not only to facilitate cowpea farmers accessing to high yielding (less sensitive) varieties but also teaching to them some innovative ecological intensification approaches and nature-based technologies that have potential impacts in terms of suppressing pest populations. For example, introducing and promoting push-pull technologies may help as such technologies have helped in reducing pest attacks to maize in East Africa (Kenya). Also, new landscape and habitat approaches in areas where cowpea is cultivated are needed in order to enhance the delivery of ecosystem services (biocontrol, pollination services) in cowpea fields from nearby field margins and semi-natural habitats. For example, enriching legume cover crops may increase the population density of parasitoids and predators of major cowpea pest species. Eliminating natural enemies non-host crops/plants in fallows and vegetation in the filed margins found in the vicinity of cowpea fields, while promoting crop rotation pattern and the cultivation of tolerant/resistant genotypes, may help farmers obtaining optimal yields. Integrating climate-smart farming practices and related resilient farming systems may help in cutting down insect pest populations in fields where tolerant varieties have been planted.

In Lomami province, rather that promoting integrated pest management (IPM) approach, it may be important to encourage natural control of pests. High population densities of natural enemies of crop pests have the potential of establishing rapidly in the agricultural landscapes since the landscape in not over cultivated: few gardens are found generally spread in large natural landscapes. Cultivated gardens occupy about 5% of the total landscape while 95% of the landscape is generally covered by savannah vegetation. It is believed that enriching the natural vegetation found on over the 95% of the landscape with food plant species for parasitoids and predators, it is possible to strengthen the natural delivery of biocontrol agents in cowpea fields.

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