

Original Research Article

Potentials of Arbuscular Mycorrhiza Fungi (AMF) and neem (*Azadirachta indica* A. Juss.) leaves extract as biological control agents against the sweet potato weevil (*Cylas puncticollis* Boh.) in two agro-ecological zones of Cameroon

Abstract

Sweet potato (*Ipomoea batatas* (L.) Lam.) ranks second in production and value after cassava among the root crops in Cameroon. Its production has been declining mainly due to the damaging effects of *Cylas puncticollis* Boheman (Coleoptera: Apionidae), its primary pest. Therefore, this study was carried out to determine the effectiveness of Arbuscular Mycorrhiza Fungi, aqueous neem leaves extract and synthetic chemical fertilizer-NPK against *C. puncticollis*. The experiment was conducted under field conditions at Garoua and Ngaoundere, respectively in the agro-ecological zone I and II, and during the two consecutive cropping seasons of 2013 and 2014. Results indicate that, whereas mycorrhiza improved the stem length by 58 and 64%, the combination neem-mycorrhiza did so by 59 and 66%, respectively for the local and the TIB1 sweet potato varieties compared to treatment control that weakly enhanced the stem length. Neem-mycorrhiza and Arbuscular Mycorrhiza alone in this order contributed to a significant ($p < 0.05$) reduction of damages caused to the local sweet potato variety by *C. puncticollis* within the two agro-ecological zones. Among the cultivated varieties used in the field, the local variety proved to be more resistant to pest infestations, despite its low yield (12.65 t/ha) compared to the improved variety TIB1 (15.82 t/ha). At the end of this study, it is suggested to recommend mycorrhiza and neem leaves extract as a local sustainable solution to reduce *C. puncticollis* damages in northern Cameroon.

Key words: *Cylas puncticollis*, *Ipomoea batatas*, Arbuscular Mycorrhiza Fungi, aqueous neem leaves extract, damages severity, crop yield.

1. Introduction

Sweet potato [*Ipomea batatas* (L.) Lam.] is a plant belonging to the Convolvulaceae family. It is originated from South and Central America [1, 2], and is cultivated in almost all the continents for its tubers and leaves that are consumed by human and livestock [3]. Sweet potato production is ranked seventh among the main world nutrients, after barley, maize, rice, Irish potato, millet and cassava [4]. In Africa, averagely 90% of production is made for human consumption [2].

However, sweet potato production is suffering from several environmental constraints

[5]. The plant is attacked during its growth stages by devastating insects, fungal and bacterial diseases that infest different vegetative organs [6]. *C. puncticollis* happens to be the major pest of sweet potato that causes damage in the field and in storage. Losses due to *C. puncticollis* have been estimated up to 80% [7], or between 60-100% [8], contributing to reduced yield of up to 97 % [9, 10] either in the field [11], or in storage [12].. The principal form of damage to sweet potato by larvae are either directly through mining of the tubers which become riddled with cavities, spongy in appearance and dark in color, or indirectly by facilitating entry of soil-borne pathogens [13]. Even low levels of feeding induce chemical reaction that imparts a bitter taste and terpene odor to the tubers. The adult may feed on tubers, creating numerous small holes that measure about the length of their head [14].

In Cameroon like elsewhere, constraints to sweet potato production have been reported [15, 16]. Generally, the control of devastating insects for yield improvement is usually accomplished through utilization of chemical inputs [17]. Unfortunately, the negative impact of chemical inputs on beneficial insects, soils, water, and additionally its elevated cost that rural farmers will not be able to afford have been reported [18,19]. In the world, more than 20.000 deaths have been attributed to these chemicals intoxication [20]. Synthetic insecticides have demonstrated their limit against *Cylas* spp, since they fail to penetrate inside tubers and sweet potato stem where the pest insects are abundant. Hence, it is necessary to explore other environmentally friendly alternative measures to reduce the incidence of this important pest.

Botanical extracts are broad spectrum materials used in pest control, because they are safe to apply, unique in action and can easily be processed. Locally available plant materials have been widely used in the past to protect the plants from damage caused by insects [21]. The main advantage of botanicals is that they are easily produced by farmers, cheaper and hazard free in comparison to chemical insecticides [19, 22]. Plant based extracts have been reported efficient against certain pests [23].

Other microorganisms such as Arbuscular Mycorrhiza Fungi (AMF) establish a symbiotic relationship with plant roots, in which each of the partner gain benefits from the other [24]. The role of AMF in nutrient uptake has been attributed to increase total absorption surface of infected plants, leading to improvement of its access to immobile nutrients such as P, Cu, Ca, and N in areas beyond the depletion zone [25]. Most of the earlier studies suggest that roots colonization with efficient AMF significantly improve phosphorus nutrition, and

consequently nitrogen fixation, probably by stimulating the nitrogenase activity [26], or by enhancing photosynthetic nitrogen use efficiency [27]. The mechanisms that explain the protective activity of mycorrhiza include the improvement of mineral nutrition that renders plants more vigorous and resistant [28], the compensation of loss of biomass, through the extra-roots hyphae that increase nutrient uptake area, the increased concentration of amino acids found in exudates of AMF colonized roots [29]. The ability of AMF to act as biological control agents against flower thrips such as *Megalurothrips sjostedti* was demonstrated [30].

The present study focused on neem (*Azadirachta indica* A. Juss.), which is a plant biocide with the active principle called azadirachtin [31]. All the neem plant parts present an insecticide effect, and are widely used in traditional medicine [32]. The plant extracts have demonstrated their efficacy in the control of more than 400 harmful arthropods including *C. puncticollis*, but also on reduction of plant diseases [20, 33]. Compared to synthetic insecticides, plant extracts have not yet been reported to stimulate development of resistance against a particular pest [20], although azadirachtin has been revealed to reduce the number of some rhizospheric microorganisms [34]. The main objective of this study was to optimize sweet potato yield through the control of *C. puncticollis* using mycorrhiza and neem extract as biological control agents. The biological control potentials of AMF, neem extract and chemical fertilizers are discussed and compared.

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86 **2. Materials and Methods**

87 **2.1. Study site**

The study was carried out within the campus of the University of Ngaoundere (Dang), and at IRAD Garoua (Kismatari) for two successive years (2013 and 2014). The Adamawa Region (Cameroon) covers about 62000 km² and belongs to the agro-ecological zone II known as the Guinean savannahs with six months dry and raining season each [35]. The study site was located at latitude 7° 32' 38", at longitude 13° 51' 125" and at 1100 m elevation. Garoua belongs to the Sudano-sahelian zone or agro-ecological zone I with nine months dry season and only three of raining season. The climate is characterized by low precipitations between 400-1200 mm/year, and temperature ranging between 28 and 45°C. The study site was located at 9° 18' 5" N, 13° 23' 51" E at 244 m elevation.

96 **2.2. Plant material**

Explants were stem fragments of two sweet potatoes varieties, of which one was the local variety, and the other an improved Tropical *Ipomea Batatas* 1 (TIB1) variety. The TIB1 variety, which produces white tubers was developed by the international Institute of Tropical agriculture

(IITA), and vulgarized by the Institute for Research and Agricultural Development (IRAD) within the Adamawa region. With a growing cycle of 120 days, it is characterized by a yield of 18t/ha if the plant density is 30.000/ha [36]. In total, 1200 stem fragments measuring 30 cm long each were used as described [13].

2.3. Experimental design and treatments

The experimental design used in the field was a two-factors split plots $(5 \times 2) \times 4$, in which the main factor or treatments was represented by inoculation or not of plots with mycorrhiza, Neem extracts or application of chemical fertilizer-NPK (20:10:10), whereas the second factor or sub-treatments was the sweet potato variety (TIB1, local). The experimental field consisted of 40 experimental units (4 x 1) m² with 30 cm elevation. The 5 treatments, each of which was replicated 4 times were: Abuscular mycorrhiza fungi (AMF), in which explants were inoculated at sowing with 20g of the mycorrhizal inoculum in a layer; Chemical fertilizer-NPK-20:10:10 (ChFert), in which explants were not inoculated at sowing, but were applied with 23.33 g/plantlet of the chemical fertilizer-NPK at 30 days after sowing (DAS); Neem extract (Neem), in which explants were not inoculated at sowing, but were sprayed with Neem extract once a week in the afternoon as from 30 to 150 DAS; Neem-AMF, in which explants were inoculated at sowing with 20g of the mycorrhizal inoculum in a layer and sprayed with Neem extract once a week in the afternoon as from 30 to 150 DAS; the control (Ctrl), in which explants were neither inoculated at sowing with mycorrhizal inoculum, nor sprayed as from 30 DAS with Neem extract, or applied with chemical fertilizers-NPK.

2.4. Mycorrhizal inoculum and chemical fertilizer

The mycorrhizal inoculum was mainly composed of the hyphae fragments of *Gigaspora margarita* and *Glomus intraradices* species with 25 spores/g soil at equal concentration. Before planting, 10g of the mycorrhizal inoculum were introduced as a layer into sowing holes. The chemical fertilizer used was NPK (nitrogen-phosphorus-potassium) with a formula 20:10:10. The application was performed at a concentration of 23.33 g/plantlet at 30 DAS as described [36].

2.5. Preparation of the neem extract or bioinsecticide

To prepare 2.5L of Neem extract, 0.5kg of Neem leaves were used for a concentration of 200 g/l. Fresh Neem leaves sampled were pounded, and mixed in 20L water overnight. The mixture was sieved and filtered using a 0.5mm porous tissue [37]. The steps in the preparation are summing up in Figure 1. Spraying of plants with Neem extract was conducted

once a week in the afternoon as from 30 to 150 DAS, at a rate of 5L for each of the 4m² experimental unit.

2.6. Assessed parameters

The sweet potato productivity was quantified through the assessment of plant size using a graduated decameter (m) on 10 randomly selected plants per elementary plot (40 plants per treatment) at 60 days after sowing (DAS). Similarly, the fresh weight of tubers was evaluated on each elementary plot (EP = 4m²) using an electronic balance (Sartorius, Prodilab, France) with 0.001 sensitivity, and converted onto hectare by the following formula:

$$\text{Yield (ha)} = \text{Yield EP} \times 10000 \text{ m}^2/4\text{m}^2$$

Sweet potato tubers indicating holes dug by *C. puncticollis* were registered as damaged [38]. The attack rate was calculated through this formula:

$$\text{Attack rate (\%)} = \text{Number of attacked tubers} \times 100 / \text{Total number of tubers}$$

The damage severity was visually determined by identifying sweet potato tubers damaged and counting on each ones the holes bore by *C. puncticollis*.

2.7. Statistical analysis

All the experimental data obtained were statistically analyzed by R Commander v2.15.0 program, *via* the package R cmdr using the analysis of variance with two factors. Mean were compared between treatments using the Tukey test. Correlations between parameters were revealed using the correlation coefficient of Pearson.

3. Results

3.1. Influence of treatments sur stem length at 60 DAS

Table 1 indicates that AMF alone or associated with Neem extract was more effective in significantly ($p < 0.001$) increasing the stem length compared to treatments control and Neem alone that weakly enhanced the stem length. The improved variety TIB1 significantly ($p = 0.006$) expressed growth more than the local variety. Hence, AMF contributed by 58 and 64% in increasing the stem lengths; while this was 59% and 66% achieved by Neem-AMF respectively for the local and the TIB1 varieties.

3.2. Influence of treatments on sweet potato yield (t/ha) at harvest

Sweet potato yield was considerably ($p \leq 0.0001$) improved by treatments (Figure 2). Yield in terms of number of tubers was more elevated in Ngaoundere (20.68 t/ha) and was attributed to chemical fertilizer application on TIB1 variety. The greatest tuber yield for the local variety in Ngaoundere was obtained after application of chemical fertilizer (16.75t/ha), and in Garoua as the response to mycorrhizal inoculation (11.15t/ha). Similarly, the lowest tuber yields for the local and improved varieties were respective 5.57 and 6.74 t/ha accounting all for the control treatment.

3.3. Influence of treatments on sweet potato damages caused by *Cylas puncticollis* in the field

Different treatments significantly reduced the number of tubers attacked by *C. puncticollis* ($p \leq 0.001$, $F=29.12$, $df=19$ at Garoua 2013; $p=0.08$, $F=2.48$, $df=19$ at Ngaoundere 2013) within the two experimental zones, Neem-AMF and AMF acting in this order more than other treatments on the local potato variety (Table 2). In contrast, *C. puncticollis* induced more damages on TIB1 potato tubers from chemical fertilizer treatment (40.71%) than those of the control (38.57%), but that were significantly higher ($p \leq 0.001$, $F=161.15$, $df=19$ at Garoua 2014; $p \leq 0.001$, $F=20.56$, $df=19$ at Ngaoundere 2014) than damages due to treatments Neem-AMF and AMF. Thus, the local variety has shown to be more resistant to *C. puncticollis* attack in the field (27.85% damages) than the TIB1 (33.28% damages).

3.4. Influence of treatments on the severity of damages induced by *C. puncticollis*

Figure 3 indicates that treatment Neem and AMF contributed 52.43% and 54.35%, respectively to the reduction of the damage severity on tubers of the two varieties in the two agro-ecological zones. The severity of damages was more noticeable on the control or chemical fertilizer treated tubers than other treatments, with averagely 32 and 33 holes bore on a single tuber. Similarly, the local variety was less susceptible to attack (25 holes/tuber) than the improved TIB1 variety (29 holes/tuber).

3.5. Correlation between yield, attack rate and severity in tubers

The relationships between some studied parameters in the field are confined in table 3. Whereas the correlations between the yield and each of the severity and attack rate was non significant ($p > 0.05$), the one between severity and attack rate was positive and significant ($r = 0.77$, $p = 0.001$). In other words, the galleries dug by sweet potato weevils reduced the weight of the attacked tubers, and hence, negatively affects the tuber yield.

4. Discussion

Mycorrhiza improved stem height by 58% and 64%, while the combination Neem-mycorrhizal did so by 59% and 66%, respectively for the local and the TIB1 varieties, compared to control. These observations can be ascribed to the efficient improvement of mineral uptake by mycorrhizae, responsible for a better plant growth [39, 40]. In a greenhouse experiment, the genus *Glomus* was reported to stimulate by 83% and 51% the gain of *Argania spinosa* [41]. As far as the stem dry biomass and tuber yield are concerned, the NPK-type chemical fertilizer was the most cost-effective, compared to mycorrhizae or neem alone, and the control in this order. This was similar to previous reported results on Irish potato [42], or sweet potato [36], as the response to mycorrhizal inoculation. Elsewhere, *Sterculia setigera* plants inoculated with *Glomus mosseae* and *Glomus fasciculatum* gave the highest dry matter weights with an average value of 1.07g more than the control [39].

The two mycorrhizal strains used in this research (*Glomus* and *Gigaspora*) were shown to stimulate the uptake of nutrients such as phosphorus, potassium and calcium, manganese and copper [43]. Improved mineral nutrition resulted in significant biomass production on inoculated plants. This may be vital for the cultivation of sweet potato in the field due to its very low levels of water and nutrients contents [41].

Neem leaf extract and mycorrhizae were effective in reducing the damages caused by sweet potato weevils, although not highly significant. These results can be justified by the fact that Neem leaves extract hardly reached the tubers that are buried in the soil in which the sweet potato weevils live [5]. In addition, it is possible that Neem extracts pulverized was blown away by wind or rain, which could have contributed to decreasing their effectiveness. Neem extract was revealed to be more effective when in direct contact with insects such as caterpillars and spruce budworm [31]. Our results are in line with those indicating 69% reduction of potato tubers attacked compared to the control after Neem extract application [44]. In contrast, Neem leaf extract was reported to be less effective in controlling cowpea pests in the field, emphasizing instead their effectiveness on insects in storage [45]. The most active substance of neem is known as azadirachtin [46], which is distributed in all parts of the plant and occurs weakly in the leaves [31]. Associated with the synthetic insecticide (Diazinon), neem leaf extract was found to be effective in controlling *C. puncticollis* in Nigeria [33]. Unlike Neem leaves extract, Neem oil may contain high concentration of azadirachtin. Hence, Neem oil extract have been shown to positively reduce the brown rot of cocoa, with an optimum effectiveness at between 10-15 L/ha [17].

The results obtained show that the greatest rate of attack was that of chemical fertilizer treatment. Indeed, chemical fertilizers recorded the best productivity in terms of tubers. Elemental plots without fertilizers showed the least parasite damages as they were less attractive to *C. puncticollis* due to weak vegetative development. High productivity may lead to high sensitivity to weevil attacks [47].

The weak vegetative development of tubers and the depth rooting of plants may probably have resulted in the resistance of the local variety to the weevil [48], in contrast to the TIB1 variety, that was more susceptible to *C. puncticollis* attacks. This resistance could also be attributed to the adaptation of local varieties to the environment, or the fact that they might possess natural resistance genes to the weevil. Local varieties in southern Nigeria were found to be least infested with *C. puncticollis* than varieties recommended by IITA [13]. Treatment Neem extract was particularly effective in reducing damages caused by *C. puncticollis*. Neem acts through azadirachtin that repels insect pests [49]. The natural properties of this substance are able to prevent or reduce the severity of attack by pests [50]. Some researchers have noticed that Neem extract blocks moulting, inhibits growth and feeding habit of the insect [31, 46]. Similar results were obtained in Ghana where Neem extract was revealed to reduce the number of holes on potato tubers (4 holes/tuber) compared to the control (13.30 holes/tuber) [44]. In a recently related research, a significant control of sorghum stemborer damage was observed after application of neem kernel powder and chilli pepper powder in combination or alone [51].

Mycorrhiza also reduced attack severity, protecting roots against damages causing agents as reported [52]. The protective activity attributed to AMF includes improvement of mineral nutrition that makes the plant more vigorous and resistant [28]. The combination of mycorrhiza with neem extract was more effective. The tuber content of the local variety in nitrogen, starch, dry matter, carotene and moisture was revealed to play an important role in the resistance of tubers to pest attacks [53]. The mechanisms of resistance of sweet potato to *Cylas* sp have been reported to include antibiosis, antixenosis (non-preference), the resistance characteristics that result from polygenic transmission including root density, root depth and tuber thickness [48].

There was a negative correlation between the yield and the severity of attack signifying that the yield was closely dependent on the rate and severity of attacks. Indeed, the increase in damage severity reduced the yield. The galleries dug in the tubers by the weevils

resulted in the reduction in tubers weight. These results are in agreement with another finding that showed no significant correlation between the number of weevils and the level of damage within the studied varieties [54]. The correlation between the studied parameters in storage was significant (data not shown). In other words, the more the weevils are present, the more damage they will bear to tubers.

5. Conclusion

At the end of this experiment, it appears that the use of Arbuscular Mycorrhizal Fungi in sweet potato cultivation results in a significant improvement of yields. The incidence of weevils on tubers was not significantly influenced by the presence or absence of mycorrhiza. The severity and rate of attacks were, however, very low in most cases when AMF was combined with Neem. The relative safety of Neem extracts for most beneficial species and its biodegradable aspect make it a serious rival for synthetic insecticides that are gradually banned the market because of their harmful effects on public health and the environment. The use of Neem extracts and mycorrhiza could supplement the chemicals fertilizers-NPK. The chemical fertilizer-NPK recorded a fairly high attack rate because of the high vegetative development. Among the cultivated varieties used in the field, the local variety proved to be more resistant to *C. puncticollis* infestations, despite its low yield (12.65 t/ha) compared to the improved variety TIB1 (15.82 t/ha).

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436 Figure 1. Steps in the preparation of aqueous neem extract

437 1. Neem leaves (0.5kg); 2. Grinding of neem leaves ; 3. Mixture of Neem leaves digests in 20L tape water ; 4. Mixture of
438 leaves digest covered tonight; 5. Sieving; 6. Neem leaves extract poured in the sprayer

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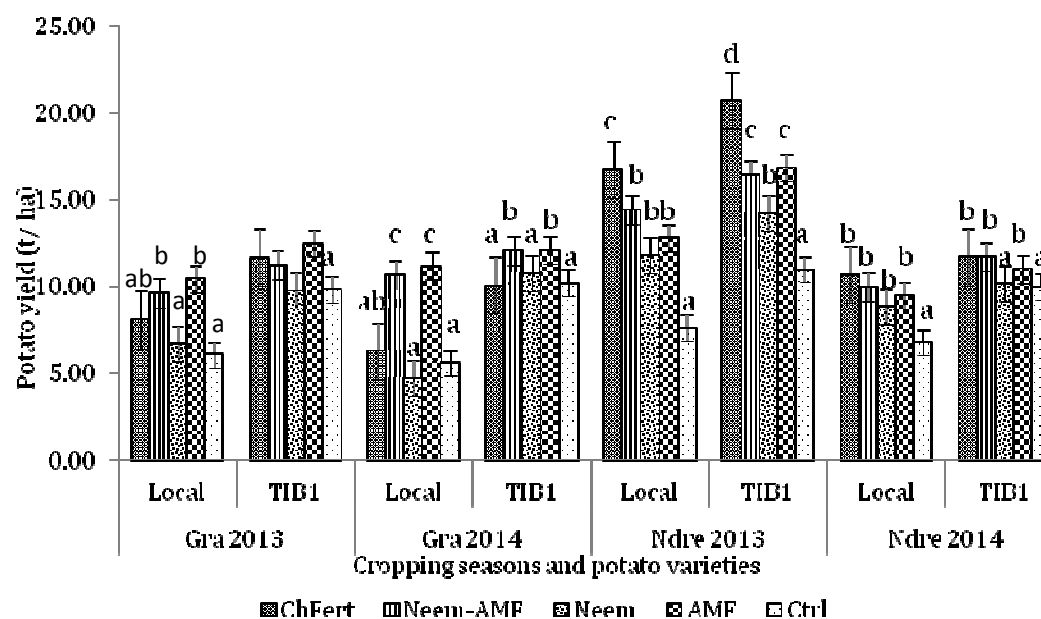


Figure 2. Changes in sweet potato yield components between varieties as affected by different treatments during cropping seasons

For each potato variety and within each cropping season, bars with standard errors (SE) of individual affected by the same letter are not significantly different between treatments at the level of probability indicated.

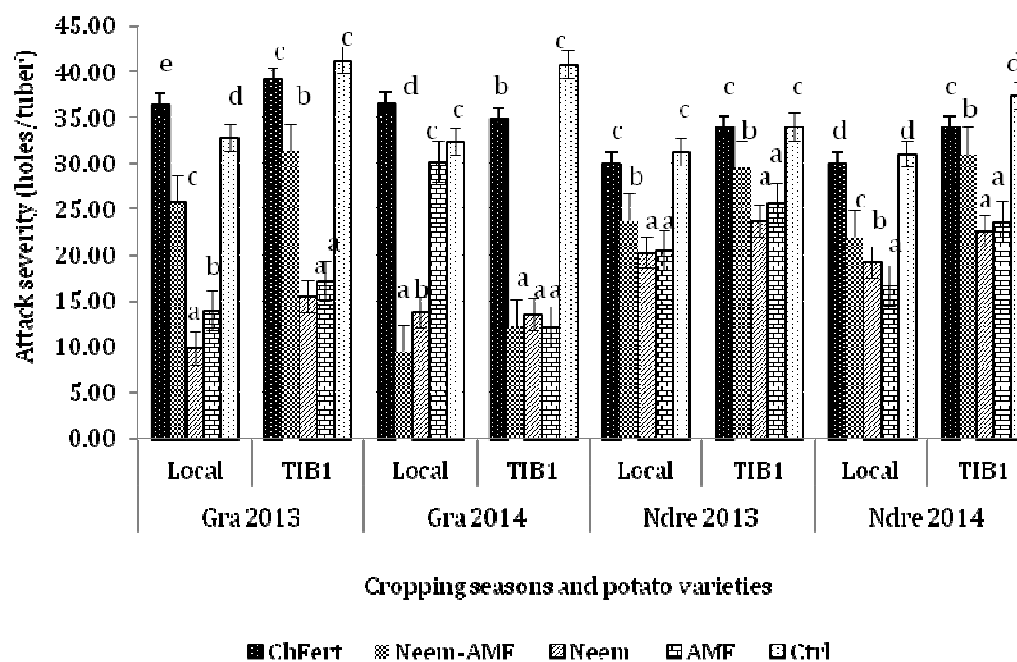


Figure 3. Variation of damage severity in potato varieties as influenced by different treatments during cropping seasons

For each potato variety and within each cropping season, bars with standard errors (SE) of individual affected by the same letter are not significantly different between treatments at the level of probability indicated.

Table 1. Variation in sweet potato stem length (m) between varieties as affected by treatments in experimental zones

Potato varieties	Treatments					F	df	p-value
	ChFert	Neem-AMF	Neem	AMF	Ctrl			
Agro-ecological zone I (Garoua 2013)								
Local	1.65±0.03 ^a _b	1.79±0.05 ^b _b	0.93±0.03 ^c _b	1.69±0.04 ^a _b	1.00±0.02 ^c _a	432.52	19	0.001
TBT1	1.85±0.03 ^a _a	2.00±0.06 ^a _a	1.12±0.04 ^b _a	1.97±0.08 ^a _a	1.02±0.12 ^b _a	157.06	19	0.001
p-value	0.0001	0.001	0.0007	0.001	0.7			
Agro-ecological zone I (Garoua 2014)								
Local	1.88±0.06 ^a _a	1.96±0.04 ^a _a	1.14±0.02 ^b _a	2.01±0.06 ^a _a	1.06±0.13 ^b _a	114.40	19	p< 0.001
TBT1	1.65±0.06 ^a _b	1.77±0.12 ^a _b	0.96±0.05 ^b _b	1.79±0.06 ^a _b	1.02±0.05 ^b _a	140.98	19	p< 0.001
p-value	0.002	0.032	0.001	0.003	0.65			
Agro-ecological zone II (Ngaoundere 2013)								
Local	2.67±0.99 ^a _a	2.82±1.08 ^a _b	1.19±0.49 ^b _a	2.77±0.99 ^a _b	1.15±0.56 ^b _a	20.22	19	p< 0.001
TBT1	3.24±1.15 ^a _a	3.74±1.23 ^a _a	1.35±0.40 ^b _a	3.63±1.18 ^a _a	1.29±0.37 ^b _a	32.82	19	p< 0.001
p-value	0.100	0.017	0.265	0.017	0.355			
Agro-ecological zone II (Ngaoundere 2014)								
Local	2.47±0.60 ^b _a	2.35±0.81 ^b _b	1.34±0.59 ^c _a	3.80±0.90 ^a _a	1.25±0.01 ^c _a	10.58	19	0.003
TBT1	3.23±0.22 ^a _a	3.32±0.14 ^a _a	1.21±0.30 ^b _a	3.39±0.17 ^a _a	1.19±0.13 ^b _a	55.86	19	0.001
p-value	0.1	0.02	0.3	0.12	0.4			

For each treatment within a column, values affected by the same lower case letter are not significantly different between varieties at the level indicated. For each sweet potato variety within a row, values affected by the same upper case letter are not significantly different between treatments at the level indicated.

484 Table 2. Variation *C. puncticollis* damages (% holes/tubers) as influenced by treatments and
485 varieties

Potato varieties	Treatments					F	df	p-value
	ChFert	Neem-AMF	Neem	AMF	Ctrl			
Agro-ecological zone I (Garoua 2013)								
Local	35.70±4.56 ^a _b	14.57±1.75 ^c _b	13.37±2.23 ^c _b	26.67±3.67 ^b _b	33.35±5.61 ^a _b	29.12	19	<0.001
TBT1	44.12±4.74 ^a _a	18.35±1.71 ^c _a	18.67±1.36 ^c _a	31.4±2.13 ^b _a	41.92±3.42 ^a _a	69.12	19	<0.001
p-value	0.043	0.021	0.006	0.067	0.040			
Agro-ecological zone I (Garoua 2014)								
Local	33.72±3.46 ^c _b	9.02±1.82 ^b _a	10.07±1.46 ^b _a	26.00±1.40 ^a _b	32.87±3.97 ^c _b	84.48	19	< 0.001
TBT1	41.35±2.54 ^d _a	6.86±0.37 ^b _a	12.45±2.36 ^c _a	32.57±4.23 ^a _a	39.97±1.23 ^d _a	161.15	19	< 0.001
p-value	0,012	0.06	0.13	0.025	0.014			
Agro-ecological zone II (Ngaoundere 2013)								
Local	33.57±7.14 ^a _a	22.14±6.75 ^{bc} _b	23.57±7.10 ^c _a	27.85±4.87 ^{abc} _b	32.14±5.89 ^{ab} _a	2.48	19	0.08
TBT1	40.1±6.33 ^a _a	29.28±7.86 ^c _a	26.42±9.14 ^b _a	31.42±6.17 ^{abc} _a	38.57±4.94 ^{ab} _a	3.01	19	0.05
p-value	0.18	0,21	0,64	0,39	0,14			
Agro-ecological zone II (Ngaoundere 2014)								
Local	31.31±2.88 ^a _b	16.47±1.82 ^b _b	19.41±4.26 ^b _a	25.23±5.81 ^{ab} _a	30.89±6.24 ^a _a	8.66	19	0.0007
TBT1	42.89±6.38 ^d _a	21.53±1.67 ^{ac} _a	18.70±2.73 ^c _a	31.05±6.00 ^{ab} _a	39.22±4.70 ^{bd} _a	20.56	19	< 0.001
p-value	0.016	0.006	0.78	0.21	0.07			

486 For each treatment within a column, values affected by the same lower case letter are not significantly different between varieties at the level
487 indicated. For each sweet potato variety within a row, values affected by the same upper case letter are not significantly different between
488 treatments at the level indicated.

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498 Table 3. Relationship between yield attack rate and severity in tubers

Parameters		Yield	Damage severity	Damage rate
Ngaoundéré (2013)				
Yield		1		
Damage severity		-0.004 ^{ns}	1	
Damage rate		-0.103 ^{ns}	0.770**	1
Ngaoundere (2014)				
Yield		1		
Damage severity		-0.1 ^{ns}	1	
Damage rate		-0.012 ^{ns}	0.75**	1
Garoua (2013)				
Yield		1		
Damage severity		-0.19 ^{ns}	1	
Damage rate		-0.11 ^{ns}	0.90**	1
Garoua (2014)				
Yield		1		
Damage severity		-0.026 ^{ns}	1	
Damage rate		-0.09 ^{ns}	0.80**	1

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