Effect of insecticide treatments and seed quality on the control of cowpea aphid borne mosaic disease

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ABSTRACT

Plants from seeds infected by Cowpea aphid borne mosaic virus (CABMV) are the only source of primary infections while aphid vectors are responsible for secondary infections. The effect of insecticide treatments against aphids and the quality of seeds on CABMV epidemics was investigated. Eight cowpea varieties were grown from virus-free seeds and also from seeds contaminated by the virus at three different rates. Disease incidence was recorded weekly during seven weeks and populations of aphids were also evaluated. Likewise, aphid's population was evaluated 30 days after sowing and a "decis-systhoate" treatment was applied. The experiment was repeated for three consecutive years (2009-2011). For each year, the results showed no significant difference between the average numbers of insects per plot. The insecticide treatment showed negative and positive impact as the number of diseased plants in average increased in some plots and decreased in others. In 2011, year of severe epidemic, the reduction rates of sick plants in treated plots varied from 1 to 16% for varieties with weak transmission power of the virus by seed and from 6 to 52% for varieties with strong transmission power of the virus by seed. In conclusion, the insecticide treatment leads to a diminution of CABMV epidemics with the two groups of varieties in the treated plots.

Key words: contaminated seeds; primary inoculums; aphids; epidemic; insecticide treatment.
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INTRODUCTION

Cowpea , *Vigna unguiculata* (L.) Walp. is a grain legume grown in savanna regions. The majority of cowpea is grown in West and Central African countries [11]. According to [4], cowpea is consumed by close to 200 million people in tropical Africa.

Cowpea's value in these areas lies in its high protein content, its drought tolerance ability, and its ability for fixing the atmospheric nitrogen, which allows it to grow on and improve poor soil fertility. However, cowpea is very susceptible to pests and diseases, which reduce yields. An entire cowpea field crop can be lost if there is no control measure against the virus [3]. [1] demonstrated that CABMV is transmitted through cowpea seed at rates ranging from 0-40 % depending in part on the host cultivar. This weakness has often resulted in severe economic damages, time wasting and too much labour consumption at seed-farmer's level.

The struggle against many pathogens as bacteria, fungi, nematods, etc. benefits the use of extensively adapted pesticides. Contrary to these groups of organisms, viruses cannot be controlled by the use of substances of type "virucide" because viruses are obligatory parasitic intracellular without own metabolic activity [6].

The control of plant viruses is thus indirectly achieved through three possibilities having each more or less efficiency according to the diseases. We can distinguish:

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- The cultural practices that's the main goal is to limit field infection by reduction of internal and external inoculums quantity. It practically concerns the adoption of measures including the use of healthy seeds, a suitable choice of sowing or plantation dates, the elimination of alternative hosts for the viruses, the eradication of diseased plants in the field, etc. In order to be effective, these measures must often lean on a good knowledge of the disease epidemiology [19].

- The genetic struggle that is based on the use of resistant or tolerant varieties. It is the most desirable means because of the fact that it is less restricting for farmer and respectful to environment while being often very effective [16]. Nevertheless, it is indispensable to have sources of resistance to the viruses and the possibility of transfer of these resistances in the desired varieties. Otherwise, an important limit to the genetic struggle is the emergence of viral variants capable to bypass resistance [6, 10, 22].

- The chemical struggle using pesticides (insecticides, nematicides, fungicides) when the virus dissemination is highly done by insect vectors of the virus.

Insecticides have been the most used pesticides for limiting either direct damages caused by the numerous insect species on plants or indirect damages caused by the viruses transmitted by insects, or for the both objectives at the same time. For example, the case of thrips that make cowpea flowers fall leading to important yield losses [15], or white flies, vectors of Gemini viruses, leading to important damages on vegetables [9].

In the case of cowpea mosaic virus and other viruses infecting this plant, chemical struggle has been used in a limitative way because of its partial success [17] but also the toxicity problems for human and environment. The low efficacy of insecticide treatments in viral diseases control is very common in the case of the viruses transmitted to the non persistent form, like the CABMV [9, 18]. Indeed, regarding the instantaneous character of removing and inoculation of these viruses, most of the insecticide treatments prove to be inoperative or increase the extension of the epidemics even by disturbing the aphid vectors and by increasing their movements from plant to plant. However, pyrethrinoides type insecticides, capable to create a shock effect by contact were revealed efficient against this type of virus. It is the case of deltamethrine (contact insecticide) and systhoate or dimethoate (systemic insecticides) as far as the vectors didn't acquire resistance to these substances.

Finally, the limits of the different methods against viruses lead to the adoption of an integrated approach involving two or several methods [5, 25]. Although this approach has been recommended in cowpea protection against viral diseases [17], few works have been carried out to define the conditions of it implementation.

Two important factors in cowpea mosaic epidemics development were cowpea variety and the seed health quality [8]. Recommendations on chemical treatments for cowpea protection suggest two applications of insecticides where the first one may take place 35 days after sowing [24]. This chemical protective regime was established in order to avoid direct damages caused by insects. During the works described in the present paper, the parameters "cowpea gentoype" and "seed health quality" have been associated to the chemical method against aphids in order to search for a best level of the disease management.

MATERIALS AND METHODS

2.1. Cowpea varieties
Eight cowpea varieties were used in the study. Three varieties named Kvx30-309-6G, Kvx414-22-72, Gorom local and Moussa local currently transmit the Cowpea Aphid Borne Mosaic Virus through seeds at rates comprised between 20 and 40% [7]. Four other varieties, Kvx61-1, Kvx396-4-5-2D, KN1 and Tvx3236 transmit the virus by the seeds at a low rate of 1 to 2% [7].

2.2. Insecticides used
Two insecticides, deltaméthrine and systhoate, were used for foliar spray. Deltamethrine ($C_{22}H_{19}Br_2NO_3$) is a pyrethroid or contact product while systhoate ($C_5H_{12}NO_3PS_2$) is an organo systemic thiophosphate whose persistence lasts two to three weeks.

2.3. Bulding of seed lots contaminated at different rates by CABMV
Seed lots contaminated by the CABMV at 0%, 0.05%, 0.25% and 0.5% level of infection were built up for Kvx30-309-6G, Kvx414-22-72, Gorom local and Moussa local. Other shares of contaminated seeds at 0%, 0.25%, 1% and 5% have also been built for Kvx61-1, Kvx396-4-5-2D, KN1 and Tvx3236. Contaminated seeds were identified by ELISA according to [12]. Seeds extracts were prepared from fragments of 60 mg taken from each seed at the

opposite side of the embryo. Virus infected seeds were mixed with virus free seeds to get seed lots of desired rates of contamination.

2.4. Field experiments
Contaminated seeds were sown in field. For each level of seed contamination by the virus, the seeds were sowed in a plot of 200 m². The soil was previously ploughed and ridged after mineral fertilization consisting of nitrogen-phosphate-potassium (NPK: 14-23-14) was applied at 100 kg ha^{-1}. Four repetitions were used that gives a total of 128 elementary plots. Two seeds were sown per hole at distances of 0.40 m between holes in the same row and 0.80 m between rows. In each repetition, plots are arranged in the increasing sense of the contamination rate. A treatment consisting to a mixture of two insecticides (deltaméthrine and systhoate) was applied 31 days after sowing at the dose of 2 ml per litre of water for two of the four repetitions.

2.5. Disease evaluation
Diseased plants were counted every week from the tenth day after sowing to the 59th day after sowing in the plots treated with insecticides and in the non treated plots.

2.6. Assessment of aphids population
The population of aphids in each plot was evaluated 30 days after sowing using the six-digits (0 to 5) evaluation scale of [20] where 0 = no infestation; 1 = 1-4 aphids per plant; 2 = 5-20 aphids per plant; 3 = 21-100 aphids per plant; 4 = 101-500 aphids per plant and 5 = more than 500 aphids per plant.

2.7. Data analysis
All data on disease incidence and aphid counting were analyzed by analysis of variance (ANOVA) [2].

RESULTS

3.1. Number of plants counted at germination
One week after sowing, a minimum of 600 plants were counted in each plot and per replicate. The number of plants has been counted in each plot of the four repetitions. Every plot had a minimum of 600 plants. This is a representative of the middle numbers of the plants in the non treated plots.

3.2. Assessment of aphids population 30 days after sowing (DAS)
The number of aphids in the plots corresponding to every initial level of seed contamination was evaluated, using the entomologists' scale. For each year, the analysis of variance showed that there was not a significant difference between the number of aphids per plot and per repetition for the first group of varieties (table 1) as well as for the second group (table 2). Similarly, according to Newman-Keuls test, no significant difference was noticed between 2009 and 2010. On the other hand, the number of aphids counted in 2009-2010 was significantly different from the number of aphids in 2011 (P<0.001).

Table 1: Assessment of aphids in the treated plots 30 days after sowing, 2009 to 2011 with susceptible and Tolerant varieties

Susceptible varieties	ICR (%) 2009				ICR (%) 2010				ICR (%) 2011			
	0	0,05	0,25	0,5	0	0,05	0,25	0.5	0	0,05	0,25	0,5
Gorom local	3	3	3	3	4	2	3	3	3	2	3	3
Kvx414-22-72	3	2	3	2	2	3	4	2	3	4	4	2
Kvx30-309-6G	3	3	2	2	3	4	3	4	3	3	2	3
Moussa local	2	2	3	3	2	3	3	3	3	2	2	4
Average	2,75 ns#	2,5 ns	2,75 ns	2,5 ns	2,75 ns	3 ns	3,25 ns	3 ns	3 ns	2,8 ns	2,75 ns	3 ns
Tolerant varieties	ICR (%) 2009				ICR (%) 2010				ICR (%) 2011			
	0	0,25	1	5	0	0,25	1	5	0	0,25	1	5
Kvx61-1	4	3	3	3	4	3	4	3	3	3	2	4
KN1	2	3	3	2	3	4	4	4	4	3	3	3
Tvx3236	3	3	3	4	4	4	3	3	3	4	3	3
Kvx396-4-5-2D	3	4	4	3	3	3	4	3	4	4	2	3
Average	3 ns#	3,25 ns	3,25 ns	3 ns	3,5 ns	3,5 ns	3,75 ns	3,25 ns	3,5 ns	3,5 ns	2,5 ns	3,25 ns

#non significant at 5% level according to Newman-Keuls' test.
ICR=Initial Contamination Rate
Aphids number has been estimated while using the following scale: 0 = not infestation; 1=1 to 4 aphids per plant; 2 = 5 to 20 aphids per plant; 3 = 20 to 100 aphids per plant; 4=100 to 500 aphids per plant and 5 = more than 500 aphids per plant

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Table 2: Assessment of the aphids in the non treated plots 30 days after sowing, 2009 to 2011 with susceptible and Tolerant varieties

Susceptible varieties	ICR (%) 2009				ICR (%) 2010				ICR (%) 2011			
	0	0,05	0,25	0,5	0	0,05	0,25	0,5	0	0,05	0,25	0,5
Gorom local	3	3	3	2	4	2	3	3	3	2	3	3
Kvx414-22-72	3	2	3	3	4	3	4	2	4	2	4	3
Kvx30-309-6G	3	3	3	2	3	4	3	4	3	3	2	3
Moussa local	2	2	3	3	2	3	3	3	3	2	2	4
Average	2,75	2,5	3	2,5	3,25	3	3,25	3	3,25	2,3	2,75	3,3
	ns[#]	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Tolerant varieties	ICR (%) 2009				ICR (%) 2010				ICR (%) 2011			
	0	0,25	1	5	0	0,25	1	5	0	0,25	1	5
Kvx61-1	4	3	3	2	4	3	4	3	3	3	4	4
KN1	3	4	3	3	3	4	4	4	2	3	3	3
Tvx3236	3	3	3	4	4	4	3	4	3	4	3	4
Kvx396-4-5-2D	3	4	4	3	3	3	4	3	4	4	2	3
Average	3,25	3,5	3,25	3	3,5	3,5	3,75	3,5	3	3,5	3	3,5
	ns[#]	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

#non significant at 5% level according to Newman-Keuls' test.
ICR=Initial Contamination Rate
Aphids number has been estimated while using the following scale: 0 = not infestation; 1=1 to 4 aphids per plant; 2 = 5 to 20 aphids per plant; 3 = 20 to 100 aphids per plant; 4=100 to 500 aphids per plant and 5 = more than 500 aphids per plant

3.3. Effect of the insecticide treatment on the CABMV dissemination for varieties having high ability of virus transmission by seeds

The propagation of the CABMV in cowpea was evaluated on varieties having high ability of virus transmission by seeds (Gorom local, Kvx414-22-72, Kvx30-309-6G and Moussa local) in treated and non treated plots. Graphs on disease progression in the plots sown with virus free seeds or different levels of contaminated seeds are illustrated in figures 1 and 2. Insecticide treatment applied at 31th day after sowing (DAS) induced more or less marked effects on the development of the cowpea mosaic. Otherwise, disease propagation was subject to important variations between years and in a least measure between cowpea varieties or between seed contamination rates. Indeed, during the years 2009 and 2010, disease incidence remained very low until 31 DAS, then, infections occurred fast. Despite this fast development of the disease, the effect of the insecticide treatments was clearly perceptible in most of the cases. The slopes of disease progression graphs for non treated plots were higher than those for treated plots. Consequently, the disease development was less important in the treated plots.

The insecticide treatments effect on the disease progression was more perceptible during the year 2011 independently of seed contamination rates. In non treated plots, the disease progression stayed regular and the incidences practically reached 100% from 52 DAS. On the other hand, in treated plots, the disease development was strongly slow down from the week following the treatment application.

Values of the area under the disease progression graphs (AUDPC) representing the intensity of the cowpea mosaic in treated and non treated plots were calculated and consigned in table 3. The comparison between these values showed highly significant differences (P <0,001) of disease development in the two types of plots. In particular, the effect of the insecticide treatment in the plots in 2011 lead to strong reductions of disease incidences in all plots independently of the initial seed contamination rates. The reduction of disease due to the insecticide treatment was most marked when virus free seeds or seeds contaminated at 0.05% were used. In 2009 and 2010, the effect of the insecticide treatment was significant in most of the cases. However, in some cases, differences between treated and non treated plots were very few marked. It was mainly about cowpea varieties Kvx30-309-6G and Gorom local expressing the genotype variations in cowpea.
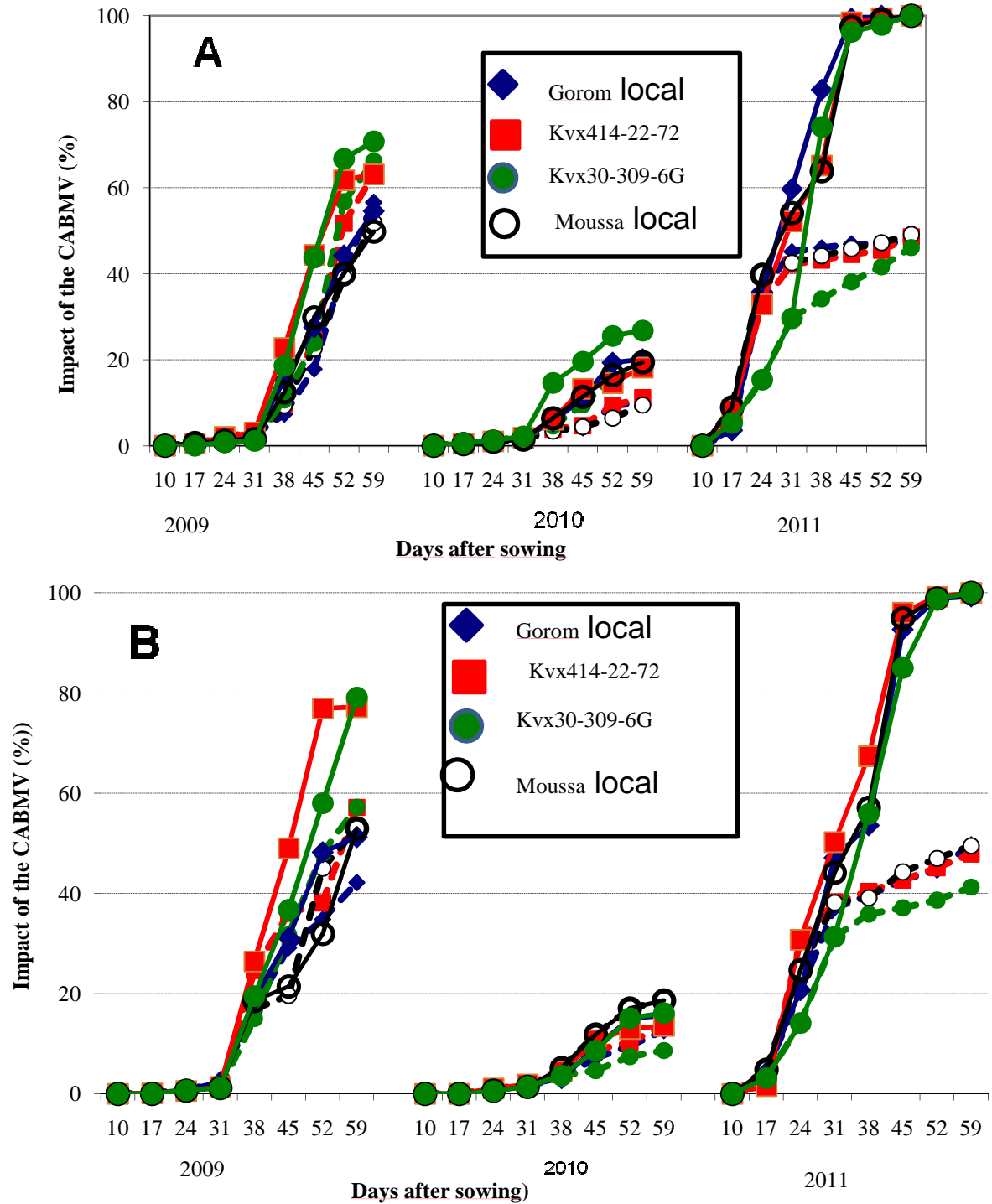
Figure 1: Propagation of CABMV in the treated plots (---) or non treated plots (→) from 2009 to 2011. The plots have been sown with virus free seeds (A) or contaminated to 0.05% (B).
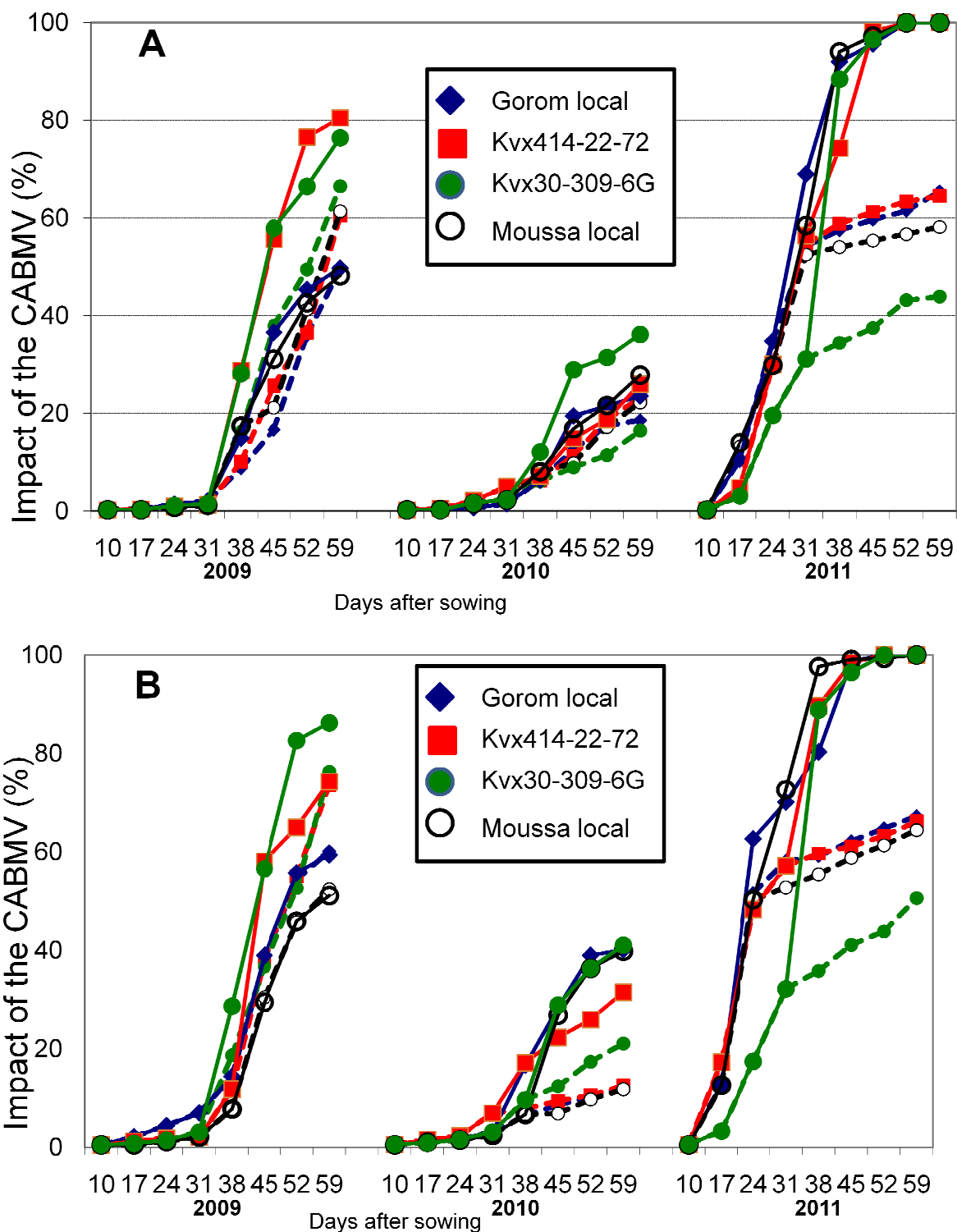
Figure 2: Propagation of CABMV in the treated plots (---) or non treated plots (→) from 2009 to 2011. The plots have been sown with seeds contaminated to 0.25 % (A) and 0.5% (B).

3.4. Effect of the insecticide treatment on the dissemination of the CABMV for varieties having low ability of virus transmission by seeds

The results on incidences assessment obtained from virus free seeds and seeds contaminated at 0.25% are illustrated in fig. 3. Disease incidence stayed less than 10% in 2009 and 2010. Even in 2011, appeared as the year of strongest epidemic, maximum infection rates were about 20% at the end of culture. Otherwise, the secondary propagation of the disease was late (28 - 45 DAS) in most of the cases. The propagation of the cowpea mosaic caused by CABMV

was low with varieties having low ability of virus transmission by seeds, in particular with the virus free seeds or seeds slightly contaminated.

Results on the use of contaminated seeds by the CABMV at 1% and 5% are illustrated by the fig 4. The disease development was more important. The final incidences reached 20% in 2009 and 2010 whereas they were near of 60% in 2011. Besides, in several cases, the secondary contamination in the plots began before 31 DAS.

Table3 : Intensity of the cowpea mosaic (AUDPC values) with varieties having high capacity of CABMV transmission by seed from 2009 to 2011 in treated (T) and non treated (NT) plots with insecticide

Rate of contamination seeds (%)	Gorom local			Kvx414-22-72			Kvx30-309-6G			Moussa local		
	NT	T	difference	NT	T	difference	NT	T	difference	NT	T	difference
						2009						
0	891.1	739.3	151.74**[a]	1353	906.8	445.83***	902.9	769.5	133.39**	1140.16	865.18	274.98***
0.05	837.5	700.2	137.31**	1166	864.5	301.1***	776.8	704.4	72.3 (NS)	1324.74	955.72	369.02***
0.25	879.9	631.4	248.48***	1429	737.2	691.45***	824.7	791.2	33.4 (NS)	1480.81	1037.96	442.85***
0.5												
						2010						
0	264.4	201.7	62.7**	265.7	232.8	32.93*	318.4	318.4	0 (NS)	664.86	155.07	509.79***
0.05	347.1	179	168.14***	327.8	191	136.75***	329.6	154.6	174.97***	543.18	301.69	241.49***
0.25	431.6	336.9	94.65***	431.3	389.5	41.76*	453.6	353.1	100.45***	664.86	273.5	391.36***
0.5	773.5	263.8	509.73***	646.7	316.6	330.1***	665.8	241	424.82***	710.08	390.98	319.1***
						2011						
0	2569	1498	1070.8***	2769	1560	1208.9***	2625	1561	1063.1***	2724.53	1267.83	1456.7***
0.05	3021	1740	1281.1***	2848	1688	1160.4***	2896	1773	1122.2***	2583.47	1313.37	1270.1***
0.25	3167	2178	988.7***	2899	2138	760.9***	3109	2037	1071.4***	2724.53	1337.54	1386.9***
0.5	3325	2398	926.7***	3230	2383	847.9***	3376	2268	1108***	2721.52	1396.24	1325.3***

[a] *non significant difference (ns), significant in P=0.05 (*), P=0,01 (* *) and P=0,001 (* * *) according to the test of Newman-Keuls*

The effect of the insecticide treatment on disease propagation didn't clearly appear in the cases where the disease incidences remained low. It concerns situations observed in 2009 and 2010 with low or non contaminated seeds by the CABMV. On the other hand in 2011, with contaminated seeds at 1% and 5%, it was possible to make a clear distinction between graphs on disease progression in treated plots and graphs in unprocessed plots.

Results from the analysis of the differences between the AUDPC values obtained respectively in treated and non treated plots were presented in table 2. They allowed to highline the effect of the insecticide treatments. Because of the low propagation of the disease in 2009 and 2010 in the plots sown with virus free seeds or contaminated seeds at 0.25%, the insecticide treatment didn't have a significant effect on the variation of the disease incidence. On the other hand, some significant differences were generally revealed when contaminated seeds contaminated at 1% or 5% were used. The biggest differences between treated and non treated plots were observed in 2011 on all cowpea varieties. With the exception of Tvx3236, the AUDPC values were very significantly low in treated plots in comparison to those observed in non treated plots.

3.5. The development of the disease before and after the insecticide treatment
In order to determine if the insecticide treatment at 31 DAS was appropriated for a good management of the disease, the values of the AUDPC, expressing the disease intensity, were calculated for each period before and after the insecticide treatment. The values were calculated based on the incidence data recorded in 2011 on seeds with the highest contamination rates. Indeed, the results presented in the previous paragraphs indicated that the development of disease was most important when seeds with the highest contaminated rates were used in 2011.

The AUDPC values were very high (between 40 and 60% of total AUDPC) for the period before insecticide treatment for cowpea varieties having a strong capacity of CABMV transmission by the seeds, except Moussa local variety (Fig 5A). On average, for these varieties, 43.3% of total disease intensity was recorded before the insecticide treatment at 31 DAS. That translates the fact that in general, for varieties having high ability of CABMV transmission by seeds, the disease development occurred early. Nevertheless, the biggest part of the infection (56.5%) occurred after the insecticide treatment. The disease intensity was a lot low (between 14% and 23%) for varieties having low ability of CABMV transmission by seeds (Fig 5B). For these varieties, the disease intensity on average before the insecticide treatment was only of 18.3%, the biggest part of the infections (81.7%) taking place after the insecticide treatment.
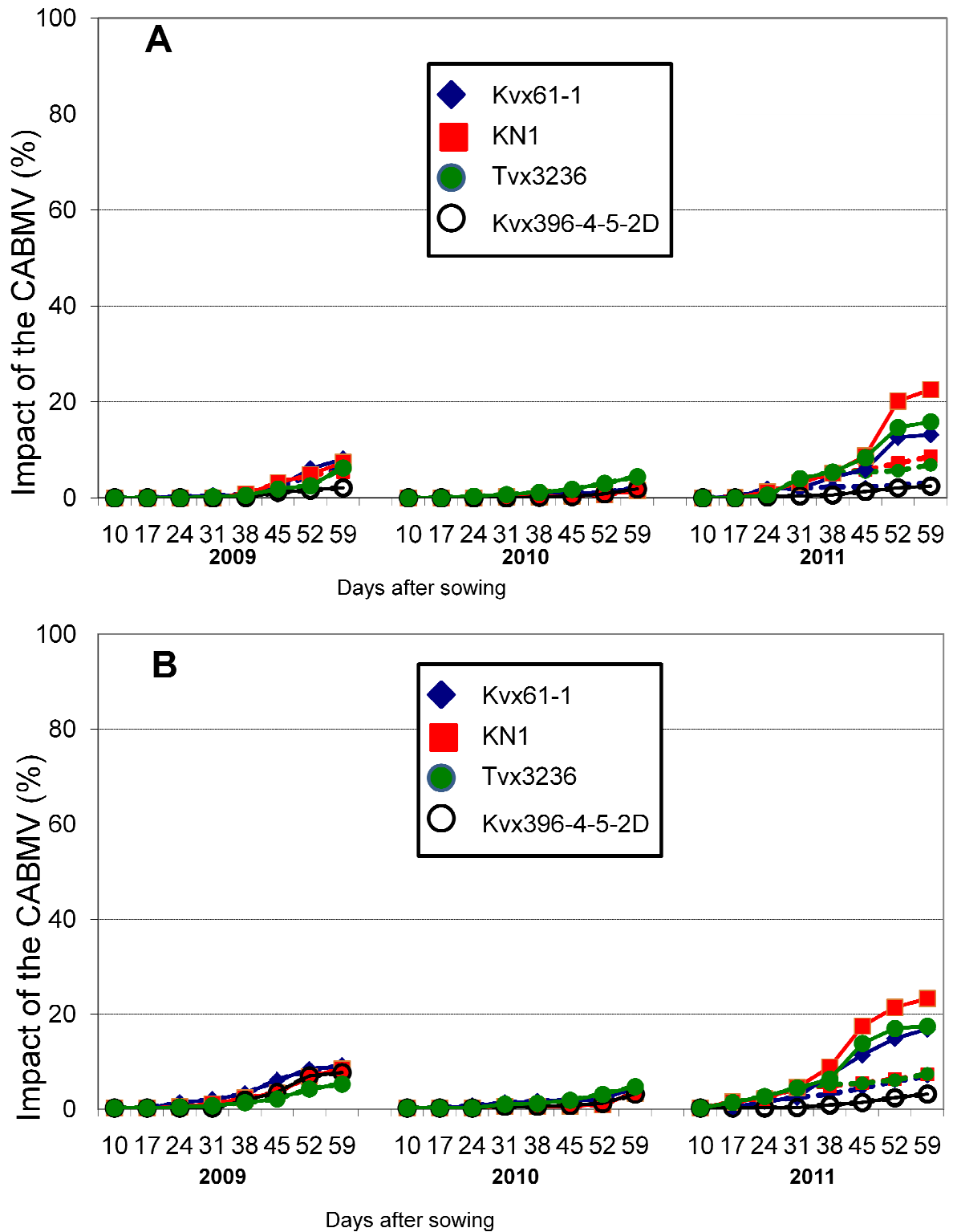
Figure 3: Propagation of CABMV in the treated plots (---) or non treated plots (→) from 2009 to 2011. The plots have been sown with virus free seeds (A) or contaminated to 0.25% (B).
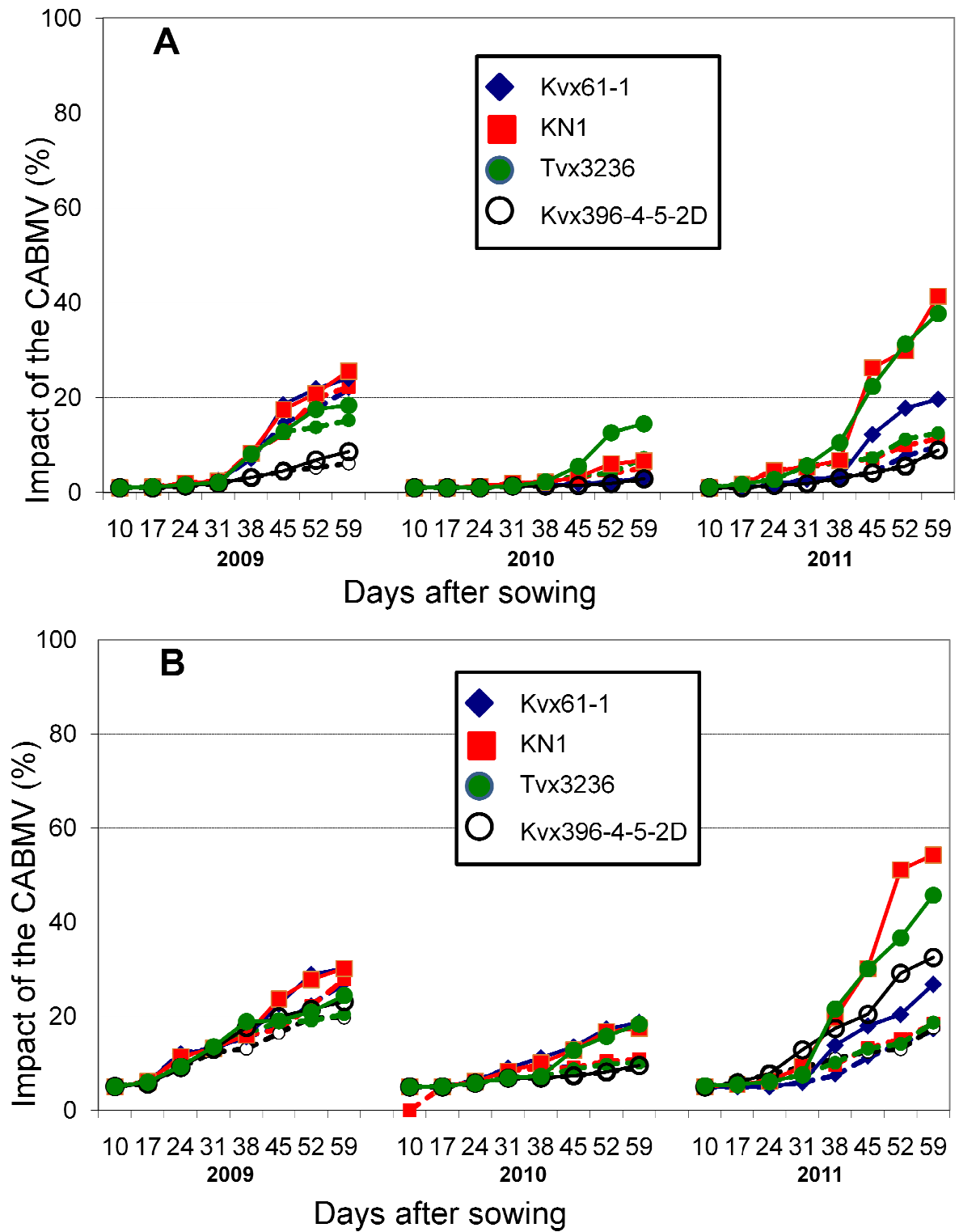
Figure 4: Propagation of CABMV in the treated plots (---) or non treated plots (—) from 2009 to 2011. The plots have been sown with seeds contaminated to 1 % (A) and 5% (B)
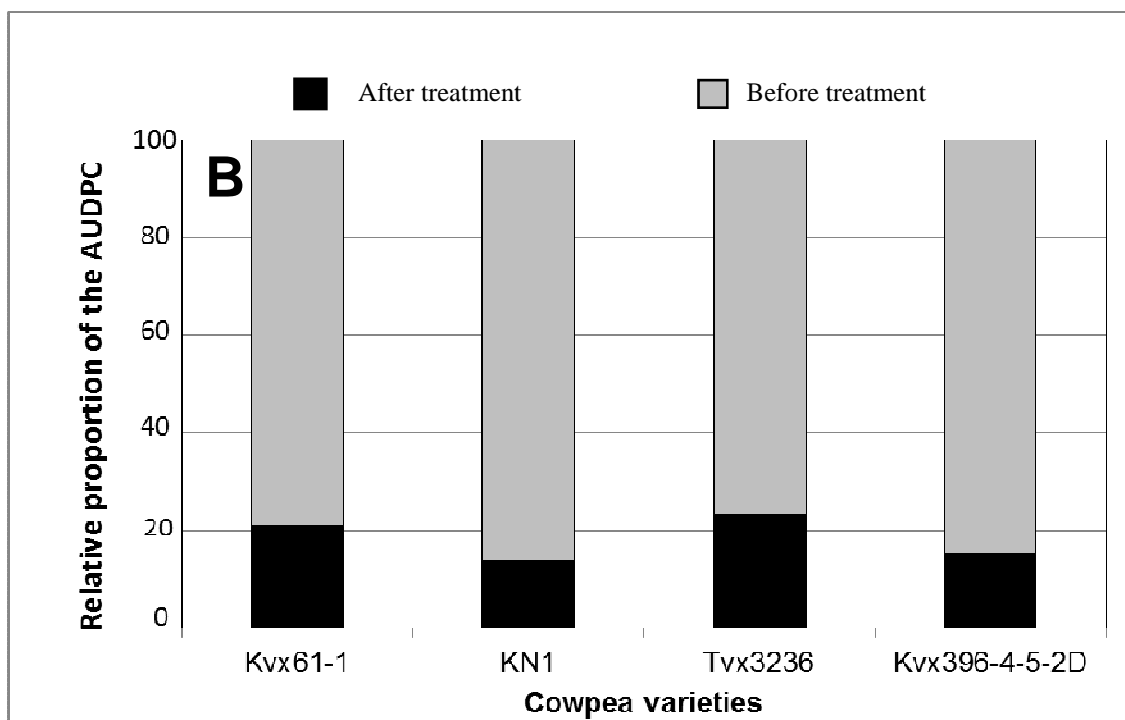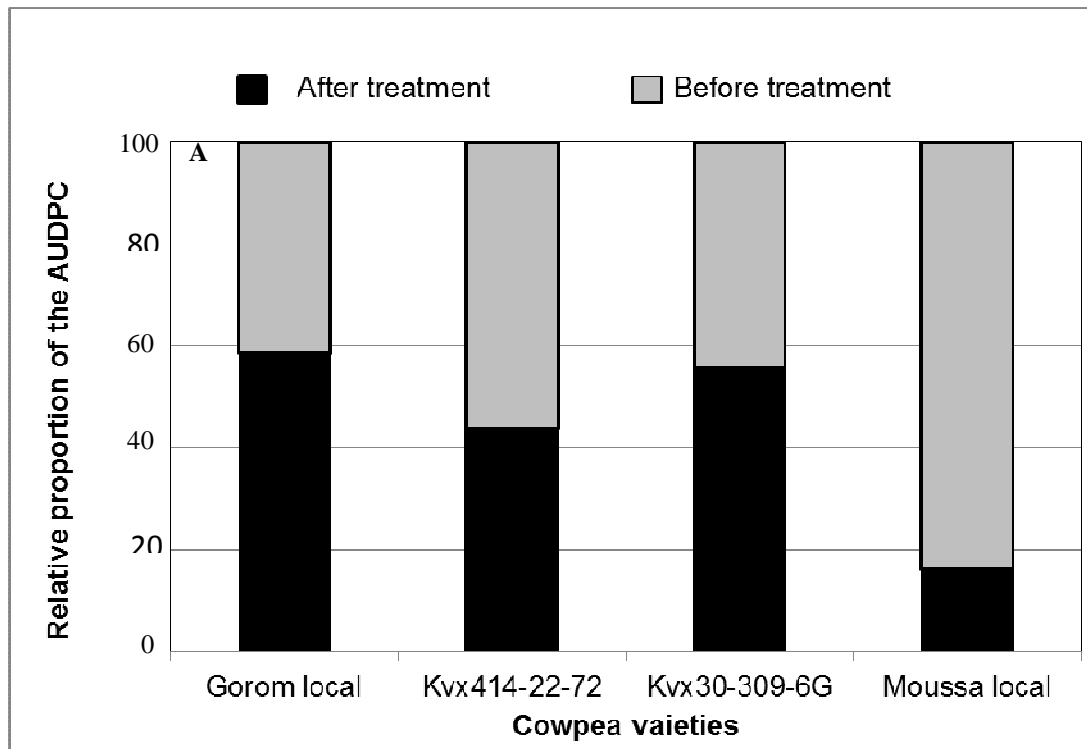
Figure.5: Intensity of the cowpea mosaic caused by CABMV before and after the insecticide treatment with the cowpea varieties having strong (A) and weak (B) ability of CABMV transmission by seeds

Table 4 : Intensity of the cowpea mosaic of the (AUDPC values) with varieties having low capacity of CABMV transmission by seed from 2009 to 2011 in the treated (T) and non treated (NT) plots with insecticide

Rate of contamination seeds (%)	Kvx 61-1			KN1			Tvx3236			kvx396-4-5-2D		
	NT	T	difference	NT	T	difference	NT	T	difference	NT	T	difference
						2009						
0	95.84	78.46	17.38 (NS) a	87.85	80.84	7.01 (NS)	28.02	28.02	0 (NS)	58.39	58.39	0 (NS)
0.25	181.76	181.76	0 (NS)	132.62	132.62	0 (NS)	120.3	120.32	0 (NS)	84.56	84.56	0 (NS)
1	457.71	392.38	65.33***	458.76	404.54	54.22***	166.6	146.07	20.52 (NS)	372.73	335.11	37.62*
5	811.31	721.43	89.88***	811.31	718.11	93.2***	707.4	621.15	86.27***	717.79	670.85	46.94**
						2010						
0	24.94	24.94	0 (NS)	16.57	16.57	(NS)	16.18	16.18	0 (NS)	65.19	65.19	0 (NS)
0.25	73.03	73.03	(NS)	37.27	37.27	(NS)	38.43	38.43	0 (NS)	72.12	72.12	0 (NS)
1	76.5	76.5	(NS)	137.56	118.11	19.45 (NS)	72.16	72.16	0 (NS)	221.48	122.92	98.56***
5	518.13	393.01	125.12***	492.67	392.21	100.46***	331.3	329.23	2.1 (NS)	457.39	358.83	98.56***
						2011						
0	234.13	89.81	144.32***	350.21	190.17	160.04***	42.03	42.03	(NS)	287.86	172.27	115.59***
0.25	325.31	150.17	175.14***	475.26	201.41	273.85***	51.77	51.77	(NS)	382.89	205.02	177.87***
1	343.59	215.84	127.75***	672.01	329.75	342.26***	255.7	186.91	68.8***	657.75	337.42	320.33***
5	588.75	418.34	170.41***	1063.55	496.83	566.72***	786.5	493.89	292.62***	931.7	479.92	451.78***

a non significant difference (ns), significant in P=0.05 (*), P=0,01 (*) and P=0,001 (* * *) according to the test of Newman-Keuls*

DISCUSSION

The chemical struggle against the potyviruses is often considered as ineffective even some chemical substances have been used with success [21]. For example, [14] showed that the use of the cypermethrin, a pyrethrinoid of synthesis permitted to reduce the CABMV acquirement and inoculation by aphids. At the opposite, other insecticide groups, such as carbamates and organophosphates proved to be very little efficient. The inefficacy of some substances resides in the fact that they don't have a lightning action on insect. In this case, the insecticide treatment, in contrary, provokes a certain excitation among the insects and multiplies it movements. Because of the non obstinate transmission of CABMV and other potyviruses by aphids, the multiplication of the movements of the vector results in an increase of the contamination of the plants. Finally, the disease impact is increased. The association of the deltamethrin belonging to the class of pryrethroids and dimethoate (organophosphate) during this work allowed reducing significantly the disease incidence in most of the cases. The efficacy of the association of these two substances probably results from the double toxicity action induced by each of the two insecticides. Indeed, while the deltamethrin is quickly acting on insects by contact, the dimethoate protects the plants in most obstinate way because of it remanence [5] (Anonymous, 2006).

The association of the insecticide treatment to the use of different seeds contamination rates permitted to obtain better disease control. In particular, for varieties having high capacity of CABMV transmission by seeds, the use of virus free seeds or low contaminated seeds (0% and 0.05%) led to strictly lower infections compared to the use of strongly contaminated seeds (0.25% and 0.5%). Similar results were obtained with the cowpea varieties having low capacity of virus transmission by seeds. Infection reduction with low contaminated seeds could be explained by [23] this equation giving the relation between the disease, the potential of inoculums and the potential of the disease: Disease = potential of inoculums x potential of the disease.

In this equation, the variable controlled by the use of different contaminated seed rates is the potential of inoculums. When this potential is low (low or non contaminated seeds), the disease level is lessened. The reduction of the potential of inoculums in particular by infected plants eradication was used with success in the management of several plant viral diseases [19]. It is thus an important cultural practice to control plant viral diseases.

The second parameter of [23] this equation presented above is the possibility of development of the disease the inoculums is available. This parameter is directly affected by the level of sensitivity of the plants subject to the infection. The results presented in this paper confirmed the effect of cowpea varieties in the development of cowpea mosaic caused by the CABMV. Thus, the infections are a lot most frequent on varieties having high ability of virus transmission by seeds. The choice of the variety is therefore an important factor in the management of the disease. This practice based on the use of less sensitive genotypes of plants is considered in general as the most efficient in the struggle against viral diseases of cowpea and plants [19, 13].

The association of the three factors (insecticide treatment, seed health quality and variety choice) showed that the disease intensity can be reduced considerably even environmental conditions are favorable to the epidemics occurrence. Indeed, the propagation of the disease was very slow in plots been with varieties having low capacity of virus transmission by seeds when low or non contaminated seeds were used. These results confirm the findings of

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many works indicating that the integrated struggle, notably against plant viral diseases, is of greater efficacy than the use of lonely control methods [5, 25].

CONCLUSION

The unique insecticide treatment realized at 31 DAS showed a certain efficiency to reduce the disease propagation. However, for varieties having high ability of virus transmission by seeds, an important part of the infections occurred before 31 DAS. This date is not therefore suitable for a good management of the disease and should intervene earlier. In other side, more than 40% of the disease is produced after 31 DAS in spite of the insecticide treatment. This result indicates the necessity of a second insecticide treatment in order to limit the disease progression. For varieties having low ability of virus transmission by seeds, the majority of the infections were observed after the insecticide treatment. Although a second treatment could permit to reduce disease incidence, the global level of the disease was low (about 20%). It is possible that the efficacy of the only one treatment increased if the pulverizations were realized at a previous date. Regarding to toxicity concerns, for human and environment, the chemical treatments should not be increased. In this optics, a treatment at a well targeted date intervening before 31 DAS would be appropriate for varieties having low capacity of virus transmission by seeds. On the other hand, for the other cowpea varieties, it is necessary to process to at least two insecticide treatments intervening one before and the other after 31 DAS.

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