



Research Article

Effect of Chemical Treatments on Pests and Diseases of Pepper (*Capsicum annum* L.)

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ARTICLE INFO

Article No.: 110912245

DOI: 10.15580/GJAS.2013.1.110912245

Submitted: 09/11/2012

Accepted: 20/12/2012

Published: 20/01/2013

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Keywords:

Capsicum annum L., chemical treatments, pests and diseases, yield

ABSTRACT

A study on the effects of chemical treatments of pests and diseases on pepper (*Capsicum annum* L.) was carried out at the Institute of Agricultural Research for Development in Cameroon. The trial was laid out in a 4 x 4 factorial design (4 varieties of pepper x 4 chemical treatments), making 16 treatments in 4 replications. The results showed that chemical treatments had highly significant effects ($P < 0.001$) on the reduction of pepper plant infections by viral diseases. To control *Fusarium* disease, fungicide treatment and insecticide + fungicide treatment gave satisfactory results. To combat fruitflies (*Ceratitis* spp., *Bactrocera* spp., etc.) responsible for premature fruit fall off, chemical treatments had highly significant effects ($P < 0.001$) on the reduction of the pests' population. The chemical treatments used during this experiment had highly significant effects ($P < 0.001$) on the number and average weight of marketable fruits harvested during the reproductive phase of pepper plants. Highly significant differences were observed in fruit yields from subplots in the following decreasing order: insecticide + fungicide, insecticide, fungicide and finally the control with no chemical treatment. Concomitantly, the total revenue and benefit margin accruing from the different chemical treatments followed the same trend.

INTRODUCTION

Pepper (*Capsicum annum* L., *Solanaceae* family, $2n = 24$) is an annual crop that originated from Central and South America. In Africa, *Capsicum* is so widely cultivated that African populations consider pepper as a fruit vegetable or as a traditional condiment. Pepper fruits are consumed fresh or dried either as whole fruit or ground, alone or in combination with a large number of other flavoring agents. The fruits are consumed in very small quantities and are considered as condiments or spices for appetite stimulation. Pepper is also used in industry as an ingredient for numerous foodstuffs, and also in certain cosmetic and pharmaceutical products (Grubben and El Tahir, 2004). Furthermore, pepper occupies a good rank among diversification crops for agricultural exports in Cameroon (PDEA, 2000). Prices are more and more attractive all year round, particularly for out of season production (between February and April). The crop therefore offers to small farmers specialized in this horticultural branch interesting incomes, thereby increasing their living standards.

In spite of the importance of pepper from both food and economic points of view, unfortunately in the field, pepper appears among the most infested crops, mostly during rainy seasons (March to October). The significant increase in pepper marketable fresh fruit yields brought about by appropriate water management, adoption of new cultural techniques and improved seeds as well as fertilizer applications appear useless if it is partly or totally lost through disease and pest attacks.

In Cameroon, different agricultural investigations have revealed that this crop is facing a certain number of major constraints: (i) fruit fall off before maturity, due to attacks of fruitflies (*Ceratitis* spp., *Bactrocera* spp., etc.), (ii) *Fusarium* attacks, causing a fungal disease characterized by senescence followed by sudden death of entire pepper plants, and (iii) a viral disease, transmitted by whiteflies (*Bemisia tabaci*) and characterized by leaf discolorations culminating in severe distortions of leaves or irreversible plant stunting. These constraints are present in all pepper commercial production zones in Cameroon, and are responsible for significant marketable fruit yield losses.

The objective of this study is to define appropriate chemical control methods against these constraints in the short or medium term. Chemical treatments, using insecticides and fungicides, or their association, appear to be emergent solutions and the most indicated at this time, while waiting for the introduction and/or creation of resistant or tolerant varieties (genetic control, less costly and environmentally friendly). The specific objective of this study is to increase pepper fresh fruit yields of the vegetable farmer in quantity and quality, in view of making it more competitive on the market of this versatile foodstuff, which is gaining importance at local, sub-regional and international levels, and

consequently, to increase his income and his living standards.

MATERIALS AND METHODS

Planting material

Three selected varieties of pepper: Safi, Big sun, Thailande and a local variety (control) constituted the planting material used for this experiment. Safi and Big sun are big sized fruit cultivars with red and yellow colors at maturity respectively. They are representative of pepper varieties widely marketed in Cameroon presently. Thailande and Local are called bird peppers, because of the small size of their fruits at maturity. Samples of mature fruits were harvested and conserved in plastic buckets for 8 to 10 days in the laboratory. This operation was to allow the seeds attain physiological maturity within the fruit, thus guaranteeing good germination and further vigor of pepper plantlets. After maceration, there was successive rincings using tap water. Clean seeds which remained at the bottom of the container were dried under shade for 4 to 5 days, until a humidity rate of 10 to 12 % was reached (a *Dickey-John* humidimeter was used for this test).

In the pre-nursery, the prepared seeds were germinated in plastic germination boxes containing sterilized top soil. Watering was done daily. The duration of pepper plantlets in the pre-nursery was 30 to 45 days.

In the nursery, plantlets of the different pepper varieties, 5-10 cm in height were selected from the pre-nursery and transplanted in perforated polythene bags filled with fertile topsoil. Watering was also done daily. Transplantation of pepper plantlets to the experimental field was done when they were about 45 days old and about 15-20 cm in height.

Chemical products (Pesticides)

In view of reducing the harmful effects of pests and diseases (fruitflies, whiteflies which are vectors of viral diseases and *Fusarium* disease), the following pesticides were used: an insecticide (cypercal® 50 EC; active ingredient: 50 g/l of cypermethrin), a fungicide (trimangol® 80 WP; active ingredient: 800 g/kg of mancozeb), and an association of both chemicals (cypercal® 50 EC + trimangol® 80 WP).

Cypercal® 50 EC is a multisite insecticide with a wide spectrum of activity. It is toxicologically classified as slightly hazardous (Class II: FAO/WHO); this pesticide is registered in Cameroon under N° 463/08/IN/HOMO/CNHPCAT/CMR. Cypercal® 50 EC is a very large polyvalent insecticide belonging to the synthetic pyrethrynyd family. This product acts by contact, ingestion and inhalation and has a preventive and curative action and a good persistence for the control of numerous insects of food and vegetable crops. It acts by a "knock down" effect: it reacts on the nervous system of the insect, causing a partial or

complete loss of the ability to move (paralysis). It is manufactured by Arysta LifeScience (France) and distributed in Cameroon by FIMEX International S.A.

On the other hand, trimangol® 80 WP is a multisite contact and polyvalent fungicide with a wide spectrum of activity. It is toxicologically classified as slightly hazardous, with possible irritation to the mucous (Class II: FAO/WHO); this pesticide is registered in Cameroon under N° 067/97/FO/HOMO/CNHPA/CAM. Trimangol® 80 WP belongs to the dithiocarbamate family, acts by contact and has a preventive action and a good persistence for the control of numerous diseases of food and vegetable crops. It disrupts the whole metabolism of the fungus: it inhibits glucose oxidation, the synthesis of nucleic acids and the degradation of fatty acids (Kome, 1979). It is a trademark of CEREXAGRI BV (France) and distributed by ADER Cameroon S.A.

Cypercal® 50 EC was used at the dose of 20 ml of commercial product in a knapsack sprayer of 15 l, or 2 l/ha; trimangol® 80 WP was used at the dose of 25 g of commercial product per knapsack sprayer of 15 l, or 2 kg/ha. Before spraying, the required quantity of emulsifiable concentrate (EC) or wettable powder (WP) was previously mixed with 1 l of water until a homogenous mixture was obtained; this mixture was then poured in the knapsack sprayer and completed to 15 l with clean water before application.

Field layout and follow up of the experiment

The experiment was laid out at the Institute of Agricultural Research for Development, Njombe Multipurpose Research Station in Cameroon (altitude: 80 m.a.s.l.; mean annual temperature: 28 °C; annual rainfall: 2900 mm; soil type: volcanic, very fertile). The experimental design was a 4 x 4 factorial (4 varieties of pepper x 4 types of chemical treatments), giving 16 treatments in 4 replications. The chemical treatments considered were as follow: insecticide (treatment A), fungicide (treatment B), insecticide + fungicide (treatment C), and the control which received no chemical treatment (treatment D). The subplot size was 5 m x 4 m (4 rows of 5 m long). The planting distance was 1 m x 1 m (giving a density of 10,000 plants/ha). Of the 4 rows planted in each subplot, observations were made on the 2 inner rows, the two peripheral rows limiting the boarder effect.

Chemicals were applied weekly on the pepper plant shoots, starting two weeks after transplanting, and they were maintained during both vegetative growth and reproductive development phases of the plants. During the reproductive phase, chemicals were applied immediately after mature fruits were harvested on a weekly basis, in order to reduce pesticide residues which could be harmful to consumers. During the vegetative growth and reproductive development phases, a total of 10 chemical applications were made. Also, in order to improve crop growth and subsequently fruit production for a longer period of time, a bulk fertilizer NPK 19-4-16 was used; it was

made up of 150 kg/ha urea + 80 kg/ha single superphosphate + 120 kg/ha potassium sulphate (making 350 kg/ha/application, or 35 g/plant/application of bulk fertilizer NPK). Four fertilizer applications were made during the cropping season, making a total of 1,400 kg/ha of bulk fertilizer NPK.

In each subplot, observations were made weekly on the severity of infection due to pests and diseases (viral infestations on the aerial parts of pepper plants, number of plants senesced and/or died, number of fruits which fell from the plant before maturity). A subjective scoring scale was used as follows: 1 = resistant; 2 = tolerant; 3 = susceptible; 4 = very susceptible. The number and weight (g) of good quality fruits harvested at maturity were also recorded.

Statistical analysis of data

Analysis of variance (ANOVA) was done using Genstat, version 4.2, and means separated using the Student Newman-Keuls test.

Economic analysis of the chemical treatments

Data were collected on the costs of pesticides; the costs on the local market in Njombe, Cameroon were considered (3,500 CFAF/kg of trimangol® 80 WP and 6,000 CFAF/l of cypercal® 50 EC). The cost of chemical fertilizers was also estimated based on their prices on the local market (18,000 CFAF/bag of 50 kg). Investigations were also made by contacting vegetable farmers on the quantity and cost of manual labor (nursery establishment, land preparation, transplantation, pesticides applications, field maintenance, and weekly harvests of mature fruits) necessary to produce one hectare of pepper; these investigations revealed that a total of 800 man-days evaluated at 1,500 CFAF/man-day was necessary to carry out these activities. On the local market in Cameroon, a plastic bucket of 15 l content is the measuring unit for the commercialization of pepper fresh fruits. It contains about 5 kg of fresh fruits which are sold at 5,000 CFAF. At the end of the estimations, the benefit-cost ratio (r) was calculated. It was computed as: Benefit-cost ratio (r) = Total benefit/Total cost. This implies that for every 1 CFAF invested in the production of pepper, a profit of r CFAF is expected.

RESULTS

Effect of different chemical treatments on the severity of viral diseases

Observations made during both vegetative growth and reproductive development phases revealed that the chemical treatments applied during this experiment had highly significant effects ($P < 0.001$) on the severity of viral diseases on pepper plants (Table 1).

Table 1: Analysis of variance (Mean square and P-Value) relative to the incidence of viral diseases on pepper plants.

Source of variation	Degree of freedom (d.f)	Sum of squares (s.s)	Mean square (m.s)	P-Value
Replications	2	53.52	26.76	
Varieties	3	345.26	115.08	< 0.001
Error	6	26.68	4.44	
Chemical treatments	3	30.96	10.32	< 0.001
Varieties x Chemical treatments	9	7.25	0.8	0.797
Error	24	33.12	1.38	
Times of harvest	12	36.47	3.03	< 0.001
Varieties x Times of harvest	36	24.06	0.66	< 0.001
Varieties x Chemical treatments x Times of harvest	108	30.24	0.28	0.307
Error	384	100	0.26	
Total variation	623	708.97		

For instance, subplots which received the chemical treatments combination (treatment C) had a lower degree of severity to viral diseases, which varied between 1.2 and 1.8. The non-treated subplots for all the pepper varieties had the highest degree of severity, varying from 1.2 after transplanting to 3.4 by the end of the growing phase of pepper plants (Fig. 1).

The chemical treatments with insecticide alone (treatment A) and fungicide alone (treatment B) occupied intermediary positions. Globally, Thaiande variety had the lowest degree of severity to viral diseases independent of the chemical treatment applied.

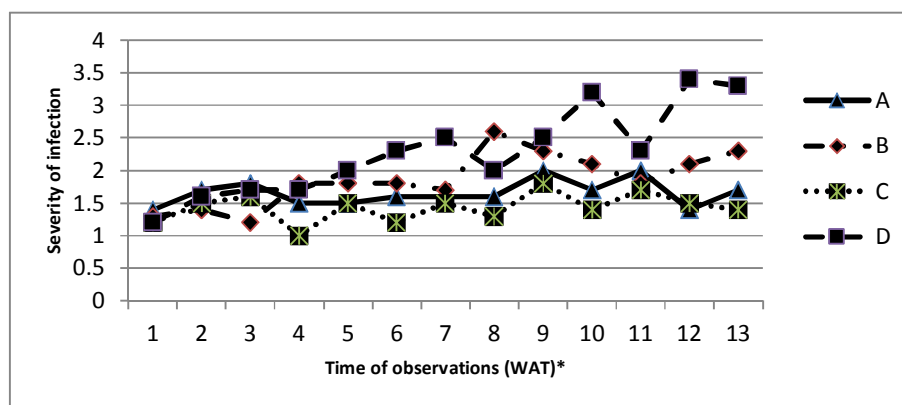


Figure 1.

A: Insecticide treatment (cypercal® 50 EC); B: Fungicide treatment (trimangol® 80 WP);
C: Insecticide + Fungicide treatment combination (cypercal® 50 EC + trimangol® 80 WP);
D: Control (no chemical treatment).

Effect of different chemical treatments on the severity of *Fusarium* disease

During the vegetative growth and reproductive development phases of the pepper plants, the different varieties had different degrees of severity to soil parasites responsible for senescence followed by plants dead. For instance, treatment B (trimangol® 80 WP) and treatment C (cypercal® 50 EC + trimangol® 80 WP) gave interesting results ($P = 0.075$) for all the pepper varieties (Table 2). The severity of infection

was very low in subplots which received the treatment combination (treatment C), varying from 1.0 after transplanting to 1.8, 7 weeks later. The severity of infection was higher in subplots which received the insecticide treatment alone (treatment A) and the control, where higher severities of 2.6 and 2.8 respectively were observed (Fig. 2). Generally, pepper plants senescence followed by plants dead, which is a disease widely encountered in all pepper production zones in Cameroon, had a very low degree of severity during this experiment.

Table 2: Analysis of variance (Mean square and P-Value) relative to the incidence of *Fusarium* disease on pepper plants.

Source of variation	Degree of freedom (d.f)	Sum of squares (s.s)	Mean square (m.s)	P-Value
Replications	2	11.19	5.59	
Varieties	3	8.01	2.87	0.23
Error	6	8.41	1.4	
Chemical treatments	3	6.41	2.13	0.075
Varieties x Chemical treatments	9	2.01	0.22	0.976
Error	24	19.67	0.82	
Times of harvest	12	62.81	5.23	< 0.001
Varieties x Times of harvest	36	11.75	0.32	0.972
Chemical treatments x Times of harvest	36	22.36	0.62	0.291
Varieties x Chemical treatments x Times of harvest	108	17.63	0.16	1.000
Error	384	21.05	0.55	
Total variation	623	382.34		

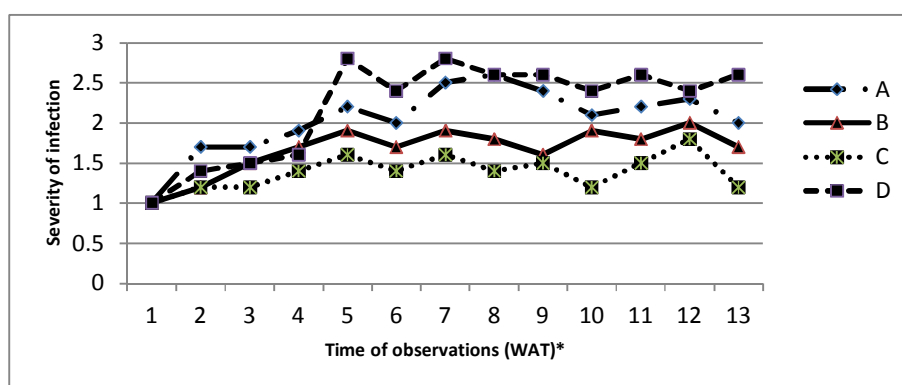


Figure 2.

*WAT: Weeks after transplantation.

A: Insecticide treatment (cypercal® 50 EC); B: Fungicide treatment (trimangol® 80 WP);

C: Insecticide + Fungicide treatment combination (cypercal® 50 EC + trimangol® 80 WP);

D: Control (no chemical treatment).

Effect of different chemical treatments on fruitflies' damages

During this experiment, damages due to fruitflies (*Ceratitis* spp., *Bactrocera* spp., etc.) which are characterized by the number of fruits that fall off before maturity varied from one chemical treatment to another during the pepper plants reproductive phase. For instance, the chemical treatments applied during this experiment had highly significant effects ($P < 0.001$) on the reduction of the pests' population (Table 3). During that same reproductive phase of pepper plants, the

severity of infection due to fruitflies' damages was significantly low in the subplots which received the treatments combination (treatment C); for this treatment, the degree of severity varied from 1.0 at the start of fruit harvest and culminated at 1.8 by the end of the crop growth cycle. This treatment was immediately followed by the insecticide treatment (treatment A) on the basis of chemical treatment effectiveness to control these pests. The severity of infection was relatively higher in subplots which received the fungicide treatment (treatment B) and finally the control (treatment D), in that order (Fig. 3).

Table 3: Analysis of variance (Mean square and P-Value) relative to the number of fruits that fell off before maturity (damages due to fruitflies) during the reproductive phase of pepper plants.

Source of variation	Degree of freedom (d.f)	Sum of squares (s.s)	Mean square (m.s)	P-Value
Replications	2	520.83	260.42	
Varieties	3	1,345.96	448.65	0.024
Error	6	398.59	66.43	
Chemical treatments	3	205.31	68.43	< 0.001
Varieties x Chemical treatments	9	520.79	57.87	0.212
Error	24	939.29	39.14	
Times of harvest	12	1,979.77	164.98	< 0.001
Varieties x Times of harvest	36	1,543.42	42.87	< 0.001
Chemical treatments x Times of harvest	36	270.91	7.53	0.984
Varieties x Chemical treatments x Times of harvest	108	1,270.01	11.76	0.814
Error	384	5,215.28	13.58	
Total variation	623	14,210.15		

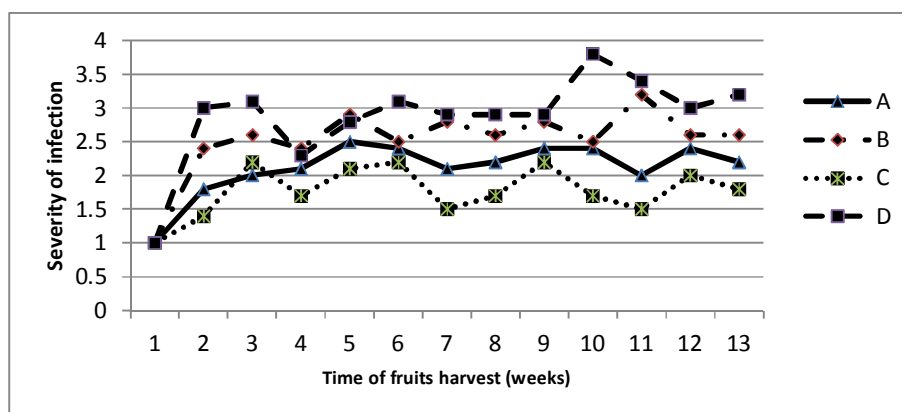


Figure 3: Incidence of fruitflies on pepper fruits over time.

*WAT: Weeks after transplantation.

A: Insecticide treatment (cypercal® 50 EC); B: Fungicide treatment (trimangol® 80 WP);

C: Insecticide + Fungicide treatment combination (cypercal® 50 EC + trimangol® 80 WP);

D: Control (no chemical treatment).

Effect of chemical treatments on fruit yield components and final yield

The chemical treatments applied during this experiment had significant effects on the increase of number of mature fruits harvested per treated sub-plot in all pepper varieties (Table 4). A higher number of marketable fruits harvested was recorded with the trimangol® treatments (treatment B) and mostly the cypercal® + trimangol® treatment (treatment C); treatment D (control) only gave lower numbers of healthy pepper fruits harvested.

On the other hand, the different chemical treatments applied during this experiment had

significant effects on the mean weight increase (g/plant) of healthy fruits harvested per treated sub-plot in all pepper varieties (Table 4). The highest marketable fruit yields were obtained in the experimental subplots which were treated with the insecticide + fungicide (treatment C: 13,524 kg/ha), insecticide (treatment A: 9,342 kg/ha), fungicide (treatment B: 7,506 kg/ha), and finally the control which received no chemical treatment (treatment D: 3,308 kg/ha), in a decreasing order. On the whole, the plots which received these chemical treatments outyielded the control by 308.82 %, 182.40 %, and 126.90 % respectively.

Table 4: Effect of chemical treatments on fruits yield component and final yield.

Treatment	Mean number of fruits/plant	Mean weight of fruits (g/plant)	Fruit yields (kg/ha)
A	381.2 ^b	934.2 ^b	9,342 ^b
B	349.2 ^b	750.6 ^b	7,506 ^b
C	601.2 ^a	1352.4 ^a	13,524 ^a
D	169.6 ^c	330.8 ^c	3,308 ^c

In the column, figures followed by the same letter are not significantly different at the probability level $P = 0.05$.

A: Insecticide treatment (cypercal® 50 EC); B: Fungicide treatment (trimangol® 80 WP);

C: Insecticide + Fungicide treatment combination (cypercal® 50 EC + trimangol® 80 WP);

D: Control (no chemical treatment).

Economic analysis of the chemical treatments

The variable cost items involved in the production process showed that the cost of pesticides varied from one chemical treatment to the other. That cost was highest when the chemical treatments were combined (treatment C: 190,000 CFAF/cropping season), followed by the treatment with insecticide alone (treatment A: 120,000 CFAF/cropping season). The chemical treatment using the fungicide alone (treatment B: 70,000 CFAF/cropping season) was less expensive compared

to the previous ones, and it was immediately followed by the control which received no chemical treatment (Table 5). The cost of other items such as mineral fertilizers and manual labor were uniform in all the four treatments. This result further showed that the chemical treatment using the fungicide alone (treatment B), the insecticide alone (treatment A), and the combination of both chemical treatments (treatment C) only increased total input cost by 4.10 %, 7.05 %, and 11.15 % respectively over treatment with no pesticide (control).

Table 5: Economic analysis of the chemical treatments.

Treatments	Cost of pesticides (CFAF/ha)	Cost of mineral fertilizers (CFAF/ha)	Cost of manual labor (CFAF/ha)	Total variable costs (CFAF/ha)	Fruit yields (kg/ha)	Total revenue (CFAF/ha)	Total benefit (FCFA/ha)	Benefit-cost ratio, r
A	120,000	504,000	1,200,000	1,824,000	9,342	9,342,000	7,518,000	4.1 ^b
B	70,000	504,000	1,200,000	1,774,000	7,506	7,506,000	5,732,000	3.2 ^b
C	190,000	504,000	1,200,000	1,894,000	13,524	13,524,000	11,630,000	6.1 ^a
D	0	504,000	1,200,000	1,704,000	3,308	3,308,000	1,604,000	0.9 ^c

Exchange rates: 1 € = 655.95 CFAF.

In the column, figures followed by the same letter are not significantly different at the probability level $P = 0.05$.

At the prevailing market price of 5,000 CFAF per plastic bucket containing 5 kg of mature pepper fruits, results of this study further showed that the total revenue yielded in plots treated with a combination of insecticide + fungicide (13,524,000 CFAF/ha) was appreciably higher than those produced in the other treatments (Table 5). Then followed the total revenue yielded in plots treated with the insecticide alone (9,342,000 CFAF/ha), and the total revenue yielded in plots treated with the fungicide alone (7,506,000 CFAF/ha). The total revenue yielded in the non treated plots was the lowest (3,308,000 CFAF/ha). The total benefit realized by the production processes showed that plants that received the combined treatment of insecticide + fungicide produced the highest total benefit of 11,630,000 CFAF. The total benefits obtained from the combined treatment, the insecticide,

and the fungicide treatments were 625.06 %, 368.70 %, and 257.35 %, respectively higher than the total benefit accruing from the control (1,604,000 CFAF). Similarly, the treatment with the combination of insecticide + fungicide produced the highest benefit-cost ratio ($r = 6.1$). This ratio was followed by treatment with insecticide alone ($r = 4.1$), fungicide alone ($r = 3.2$), and the control ($r = 0.9$), in a decreasing order.

DISCUSSION

The different chemical treatments significantly influenced the susceptibility of the different pepper varieties to the infection of viral diseases, and insecticide treatments (treatment A) and insecticide + fungicide treatments (treatment C) gave interesting results. This latter treatment has been implemented to

reduce the number of applications, as the main objective targeted by the mixture is the synergistic action of both insecticide and fungicide. For instance, viral diseases on pepper are present in almost all the pepper farms in Cameroon, the principal causal agent being Potato Virus Y (PVY): these viruses are responsible for leaf discolorations, which may culminate to leaf distortions and even to plant stunting. At that advanced stage of the disease, the situation is irreversible, resulting in a significant reduction in marketable fruit yields. Efficient control against PVY is based essentially on an efficient chemical control against whiteflies (*Bemisia tabaci* L.), which are vectors of the disease (Maruthi *et al.*, 2003), and on the use of tolerant varieties (genetic control) such as Thailande which was evaluated during this study: this pepper variety could possess genes of resistance for this particular parameter studied, and consequently could be used as a parent during intra-specific crosses in view of producing hybrid varieties resistant or tolerant to viral infections and possessing a high yield potential.

Chemical treatments are more efficient when applied as a preventive measure, immediately after crop transplantation in the field. Chemical treatments efficiency against viral diseases is increased when the vegetative growth of pepper plants is accelerated, by an appropriate choice of land and mineral and/or organic fertilization schedules (Aliyu, 2000). Alternative control methods such as odoriferous traps, which exert either attractive or repellent effects on the vectors (Boucher *et al.*, 2003) could be prospected, in order to keep the population at an acceptable level and avoid economic fruit yield losses.

Concerning the control of *fusarium* disease, the fungicide treatment (treatment B) and insecticide + fungicide treatment (treatment C) gave the most interesting results. Similar observations have already been reported by other authors (Flors *et al.*, 2001). This disease is present and highly devastating in most pepper

production zones of Cameroon; it is at the origin of considerable marketable fruit yield losses. In gardens, chemical treatments should be applied weekly immediately after mature fruits harvest: the interest of that agronomic practice is to reduce toxic residues of pesticides on fruits ready for commercialization and/or consumption. Similar observations had already been reported by other authors (Antonius, 2004). Furthermore, it is advised to use tolerant varieties and also to avoid growing solanaceous crops (tobacco, irish potato, etc.) successively on the same piece of land. *Fusarium* disease has devastating effects on soils with poor drainage. These principles should be taken into consideration when choosing and preparing land for pepper production, as earlier reported by other authors (Chellemi, 2006). On the whole, to be in line with the current principles of integrated pest management, it is recommended to prospect ecologically based approaches to control pepper diseases, such as appropriate mineral and/or organic soil fertilization and amendment schedules, as earlier reported by other authors (Kim *et al.*, 1997).

Fruitflies (*Ceratitidis* spp., *Bactrocera* spp., etc.) cause enormous damages on pepper populations, laying their eggs in immature fruits: larvae development after eggs hatching is responsible for premature infested fruit fall from the plants in pepper gardens. The action of chemical treatments is achieved through the destruction, repelling or at least the reduction of pests' populations, in view of preserving pepper fruits from damage. Similar results had already been reported by other authors (Seal *et al.*, 2009). Furthermore, injuries caused on pepper by fruitflies are responsible for enormous harms to Cameroonian farmers, as such infested products have a considerably reduced market value.

Furthermore, the chemical treatments used during this experiment had significant effects on yield parameters: the number and mean weight of healthy fruits harvested during the reproductive phase of pepper plants. These results allow us to suggest that solanaceous crops are amongst the most infected in horticultural farms, and the insufficiency or absence of chemical treatments could lead inexorably to significant marketable fruit yield losses, as earlier reported by other authors (Daniell and Falk, 1994).

However, most pesticides have been designed to kill a large spectrum of pests: they therefore have a large spectrum of toxicity, and are harmful to both natural enemies and pollinators which play an important role on fruit yields, environment, human and animals, as reported by other authors (James *et al.*, 2010). A particular accent should therefore be put on the conception and manufacturing of selective pesticides in view of significantly increasing the production of pepper, a versatile crop which nowadays occupies a good rank among the diversification products of agricultural exportation in Cameroon. Considerable efforts should also be made towards the use of different local plant resources, such as neem (*Azadirachta indica*) or garlic (*Allium sativum*) to manufacture natural pesticides, as these are efficient, economical, and less harmful to plants, consumers and the environment (Ogbalu, 1999). Consequently, cropping systems less harmful to the environment otherwise known as organic agriculture could be envisaged, as their products are highly demanded on the international market and also have a very high market value than products from conventional agriculture (Chellemi and Rosskoft, 2004).

The results obtained from this study show that pepper is a "minor" or "neglected" food crop, but which instead has great potential revenues per cropping season (5-6 months). With the highest total revenue of 13,524,000 CFAF (treatment C), pepper then deserves to occupy a good rank among diversification crops of agricultural exportation in Cameroon. This treatment also registered the highest benefit-cost ratio ($r = 6.1$), which implies that for every 1 CFAF invested in the production of pepper, a total benefit of 6.1 CFAF is expected. On the other hand, the control (treatment D) gave a significantly lower benefit-cost ratio of $r = 0.9$: pepper production should therefore not be envisaged if appropriate phytosanitary measures are not readily available in sufficient quantity during the cultivation of

this crop. Similar recommendations had already been made by other authors (Cruz et al., 1984).

On the whole, pepper production, if well managed may be considered a profitable business which can reduce rural exodus and improve the living standards of the rural poor in Cameroon. The demand for this commodity is ever increasing all year round and prices become more and more attractive in local, regional and international markets. Local farmers could therefore conquer more shares on the market of this versatile crop which is gaining importance worldwide. Similar observations had already been made by other authors (DeWitt and Bosland, 1996).

CONCLUSION

The chemical treatments combination (treatment C) and the insecticide treatment (treatment A) had highly significant effects on the severity of viral diseases on pepper plants. Also, the chemical treatments combination and fungicide treatment (treatment B) gave interesting results for the control of pepper plants senescence followed by plants dead (*fusarium* disease). In addition, the severity of infection due to fruitflies's damages was significantly low in the subplots which received the combination treatments (treatment C). Finally, the chemical treatments applied during this experiment had significantly positive effects on number and weight of marketable fruits yields from subplots in the following decreasing order: insecticide + fungicide, insecticide, fungicide and finally, the control with no chemical treatment. The total revenue and benefit margin accruing from the different chemical treatments followed the same trend. As most pesticides are designed to kill a large spectrum of pests and are therefore harmful to both natural enemies and pollinators, new perspectives could be granted to the conception and manufacturing of selective pesticides as they are less harmful to plants, consumers and the environment.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the assistance of the field staff of the Horticultural Unit, Njombe Multipurpose Research Station, and of Koudiekong Lazare for statistical analyses.

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