Sciences & Nature Vol. 8 N°1: 53 - 62 (2011)

Article original

Effects of the numbers of foliar insecticide applications on the production of the oilseed watermelon *citrullus lanatus*

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Received 08-06-2010, accepted 20-01-2011.

Abstract

Citrullus lanatus is a creeping annual vine species belong to Cucurbitaceae. This plant is cultivated for its oleaginous seeds that are important in the social and cultural life of several peoples in Africa. Thus to improve its production field studies were conducted during two cropping seasons of 2007 to define an economically beneficial foliar insecticide application frequency to manage insect pests on the oleaginous *C. lanatus* in a woodland savannah zone of Côte d'Ivoire. Zero (control) to four sprays of a foliar carbamate-based insecticide (Cypercal EC 50) were applied at four plant growth stages (seedling emergence, stem creeping, male flowering, and female flowering) in a completely randomised block design experiment. Four beetles and one ladybird species were identified as the most damaging insect pests on the target crop. Seed yield and most of the yield components analyzed increased with increasing number of sprays, the highest values being obtained with 3-4 sprays, according to the growing season. Between seasons variations were noted for the seed yield and all the yield components, and attributed to the negative influence of low temperature and heavy rainfalls occurring during the second growing season (18 July to 16 December 2007).

Keywords. Foliar insecticide, Carbamate, *Citrullus lanatus*, Cucurbitaceae, Yield, pest insects, beetles, ladybird.

Résumé

Influence du nombre d'application d'insecticide foliaire sur la production de la cucurbite à graines oléagineuse Citrullus lanatus

Citrullus lanatus *est une plante rampante appartenant à la famille des cucurbitacées. Cette plante est cultivée pour ses graines oléagineuses qui jouent un rôle important dans la vie socio-culturelle de plusieurs peuples en Afrique. Ainsi, pour améliorer sa production les travaux de terrain ont été menés en 2007 au cours de deux saisons de cultures dans la région savanicole de la Côte d'Ivoire. L'objectif de cette étude était de déterminer la fréquence d'application d'insecticide économiquement avantageux pour les paysans, afin de contrôler les insectes ravageurs de* C. lanatus *à graines oléagineuse. Zéro (Témoin) à quatre pulvérisations d'insecticides foliaires à base de carbamate (Cypercal CE 50) ont été appliqués à quatre stades phénologiques des plantes (levée des plantules, tige rampante, floraison mâle et floraison femelle) dans un dispositif à bloc complètement aléatoire. Quatre coléoptères et une coccinelle ont été identifiés comme étant les principaux insectes ravageurs de cette culture. Le rendement et la plupart des composantes du rendement analysés augmentent avec la fréquence d'application d'insecticide. En effet, les valeurs les plus élevées de ces paramètres testés sont obtenues avec trois ou quatre pulvérisations, selon la saison de culture. Par ailleurs, cette différence observée est attribuée à l'influence négative de la basse température et aux fortes pluies survenues au cours de la deuxième saison de culture (18 Juillet to 16 Décembre 2007).*

Mots-clés. *Insecticide foliaire, Carbamate,* Citrullus lanatus*, Cucurbitaceae, Rendement, Insectes nuisibles, Coleoptères, coccinelle.*

1. Introduction

The current agronomical challenge of many developing countries is to ensure the food security for their increasing population (Kishindo, 1996; Rernpel, 1998). Although agriculture employs over 85% of the population in these countries (Rena, 2007), the sector has never reached a sufficient level of productivity, to resolve the problems of famine.

Côte d'Ivoire, like numerous Sub-Saharan countries, holds remarkable plant genetic resources that remain unexploited in agriculture. Agronomic researches conducted in the past had neglected subsistence crops, as compared to cash crops. Among the subsistence crops from Côte d'Ivoire, five edible oilseed cucurbit species are cultivated mainly for their oleaginous seeds. These seeds are important in the social and cultural life of several people (Badifu, 1991; Zoro Bi *et al.*, 2003). *Citrullus lanatus* (Thumb.) Matsum. & Nakai is one of the most widely distributed and consumed at both rural and urban levels in Sub-Saharan Africa (Zoro Bi *et al.*, 2005; Achigan-Dako *et al.*, 2006).

C. lanatus is a creeping annual vine species, with leaves deeply divided into 5-7 more or less subdivided lobes. The plant bears both male and female flowers. The male flowering period begins about 4 weeks after sowing and then followed by female flowers ten days later (Zoro Bi *et al.*, 2003; Achigan-Dako *et al.*, 2006). The flowers open shortly after sunrise and remain open only one day. The pollen is usually released before the flower opens but stays on the anthers in sticky masses. Their transfer to the stigma of the female flowers is assured by the pollinators. Those insects are essential to the production of seeds and fruits of monoceous species (Laghetti & Hammer, 2007). The species produces fruits containing edible seeds rich in lipids and proteins (Loukou *et al.*, 2007). The seeds are sold on the urban markets at a price almost three and seven times higher than cocoa and coffee, respectively (Zoro Bi *et al.*, 2003).

In spite of the economic, social and nutritional roles of this species, its production in Côte d'Ivoire is conducted only by women through the traditional cropping systems, on small plots. In several agro-systems of Côte d'Ivoire, *C. lanatus* cultivation undergoes important yield losses, due to its susceptibility to the competition with weeds and pest insects' feeding injury. One of the most serious problems encountered by farmers in the production of *C. lanatus* is the damage caused by the insects, resulting in a drastic decline of the annual production (Foster & Brust, 1995; Russo *et al.*, 1997; Edelson *et al.*, 2002; Edelson *et al.*, 2003). Some insects play a beneficial role in plant production. Thus *C. lanatus* depends on the honeybee, *Apis mellifera* L., as the main pollinator (Sampson & Cane, 2000; Gusmini, 2003; Taha & Bayoumi, 2009). *Xylocopa* bees, *Halicitid* bees, *Hypotrigona* bees, bumble bees, flies and beetles were also identified as pollen vectors of *C. lanatus* (Andrews *et al.*, 2007; Nicodemo *et al.*, 2009). Beside these useful insects, numerous other species damage the plant, thus reducing sometimes the yield over 80% (Fomekong *et al.*, 2008). According to him, about 36 families of insects visit cucurbits throughout the growing period. Striped cucumber beetle (*Acalymma vittatum* Fabricius) and spotted cucumber beetle (*Diabrotica undecimpunctat howardi* Barber) destroy stems, leaves and cotyledons of young plants in *Cucurbita pepo* L and *Cucurbita maxima* (Duchesne) in Cameroun. Cucumber beetles are also vectors which predispose plants to several diseases (Hoffmann *et al.*, 2000). Squash bugs (*Anasa tristis* DeGeer) fed on *C. lanatus* until plants death (Edelson *et al.*, 2003; Pair *et al.*, 2004). The thrips feeding on the immature cucumber fruits can result in their malformation (Shipp *et al.*, 2000). It is also reported that aphids are capable of transmitting virus (Rubio *et al.*, 2003) and bacterium (Bextine *et al.*, 2001; Pair *et al.*, 2004) to the cucurbit plants.

In tropical regions where the climatic conditions favour insects proliferation, it is difficult to maximize plant production without applying reliable control methods (insecticide application) (Sibanda *et al.*, 2000; Ajeigbe & Singh, 2006; Mendesil *et al.*, 2007). Thereby, farmers use some cultural control methods (sowing dates, cultural association) and occasionally plant-based pesticides (Peveling & Ely, 2006), but the pest control is predominantly carried out through the use of insecticide (Sibanda *et al.*, 2000).

Numerous studies have been conducted to determine sustainable methods of insecticide applications on cucurbits but divergent results are sometimes reported. To date, from experiments conducted at the Oklahoma Vegetable Research Station (USA), Damicone et al. (2007) suggested two sprays of permethrin to control squash bugs on pumpkin. In two Texas counties (Cameron and Hidalgo) a mean of 4 or 5 sprays are applied to protect cucurbits from pest insects' damage (Barrientos & Anciso, 1996). In Namibia (Eastern Africa), Maggs-kölling & Christiansen (2003) controlled aphids and cucurbit bugs on watermelon applying one spray of the insecticide Namrod. Thus, the insecticide application frequency depends on the type of insecticide used, the plant species treated, the application method, and the geographical regions. Furthermore, it appears that assessing the actual influence of a given pesticide on the productivity of any crop requires genotype and site-specific trials. The purpose of the present study was to define an economically beneficial insecticide application frequency to manage pest insects in the oleaginous *C. lanatus* in a woodland savannah zone of the centre of Côte d'Ivoire. The responses of 7 yield components were analyzed in addition to the seed yield, since such an approach provides comprehensive data that are useful for management decisions (Echarte *et al.*, 2000).

2. Material and methods

2.1. Study site

On farm experiments were conducted in 2007 in the village of Manfla (latitude 6°49'34.38" N and longitude 5°43'47.68" W) 400 km north Abidjan (Côte d'Ivoire). There are two rainy seasons separated by a short dry period (July-August) and a long dry season (December-February) at the target site. Annual rainfall varies from 800 to 1400 mm with a mean of 1200 mm, and the annual mean temperature is 27°C. The climatic parameters (temperature, rainfall, and humidity) measured during the period of the trials are showed in the Table 1. The vegetation is a woodland savannah. The study site is a natural fallow plot with vegetation mainly composed of *Chromoleana odorata* (L.) R.M. King & Robins and *Panicum maximum* Jacq. In the study area, the oilseed *C. lanatus* is usually produced during two cropping seasons in a year. In the first cropping season corresponding to the long rainy season, planting and harvest took place in March and July, respectively. The second cropping season corresponds to the short rainy season; here, seeds are sown in July-August and harvested in November-December. Two experiments were conducted in 2007, with one trial per cropping season. Sowings were done after rainy day. This corresponded to 17 March, and 18 July for the first (Season 1) and the second (Season 2) trials, respectively. Harvests took place 22 July and 16 December 2007 for the trials in Season 1 and Season 2, respectively.

Table 1. Climatic data of the study site during the experimental periods

Seasons	Climatic parameters					
	Temperature (°C)		Rainfalls (mm)		Relative humidity (%)	
	Total	Mean[a]	Total	Mean	Total	Mean
Season 1	165.1	27.52	327.62	54.60	-	69.93
Season 2	153.90	25.65	565.21	94.20	-	82.07

[a]*Monthly mean* – Moyennes mensuelles.

2.2. Plant material and experimental design

The material was obtained from the cucurbit germplasm of the University of Abobo-Adjamé (Abidjan, Côte d'Ivoire). We selected a medium seed size cultivar (NI119) of the indigenous oilseed *C. lanatus* widely cultivated in Côte d'Ivoire. Planting was done according to a completely randomised block design, with three replications. Each plot was 16 m x 20 m and received 30 holes at a depth of 3 cm, arranged in 6 rows each with 5 holes sown at spacing of 2 m apart, of between and within rows.

To ensure proper stand, five seeds per hole were sown directly and thinned to one plant per hole at the two-leaf stage. Finally 30 plants per treatment and 450 plants in total (control included) were studied. The plots were weeded weekly with a hoe to avoid interaction with weeds. Any fertilizer or irrigation was applied during the trials.

The insecticide used in the study is the foliar carbamate-based insecticide (Cypercal EC 50; Callivoir, Abidjan, Côte d'Ivoire). This insecticide acts as a contact poison and had a broad spectrum action. The doses were prepared following prescriptions from the manufacturer (8% v: v). However, the quantities applied per unit area were adjusted according to four phenological stage: a) 31.25 l ha^{-1} in seedling emergence; b) 41.56 l ha^{-1} in stem creeping; c) 125 l ha^{-1} in male flowering and d) 125 l ha^{-1} in female flowering.

Four treatments (corresponding to the insecticide applications frequencies) and a control (any insecticide application) were tested. In the first treatment (one spray), the plants received the insecticide only in stage a; in the second treatment (two sprays), the plants received at once the insecticide in the stage a and the stage b (stem creeping); in the third treatment (three sprays) the insecticide was brought in the stages a, b and c (male flowering) and in the fourth treatment (four sprays) the stage d (female flowering) was added to the three previous others stages. The application of the insecticide was made manually (Osatu Star 12 Green; www.goizper.com) when 50% of the plants in each plot reach the corresponding phenological stage (Achigan-Dako *et al.*, 2006).

Insecticide applications were stopped at 50% female flowering in order to prevent elimination of pollinators (Kevan, 1999; Palumbo *et al.*, 2001; Sharma & Abrol, 2005). The dates of spray applications and the insecticide doses used are indicated in Table 2.

To identify damaging insects of the plants, we set 10 traps in each plot. The flying (sweep nets) and soil (yellow plates) insect' traps were installed just after each insecticide application during both cropping seasons. The both insects were collected separately in the trap twice between two applications (when 25% and 50% plants in each plot reach the corresponding phenological stages). At the end of the experiment all insects collected were recorded and sent to the laboratory of Entomology of UAA for identification.

Table 2. Details of the treatments in relation with plant growth stage

Plant growth stage	Insecticide dose (l ha^{-1})	Date of spray application	
		Season 1	Season 2
50% emergence	31,25	29 March	27 July
50% stem crept	41,56	12 April	9 August
50% male flowering	125	22 April	28 August
50% female flowering	125	27 May	13 September

2.3. Data collection and statistical analysis

Yield (seeds dry weight ha^{-1}) and 7 agronomical traits identified as yield components in indigenous cucurbits (Kofû *et al.*, 2009) were selected. These yield component concerned: 1) plant survival ratio (%) calculated for each treatment as the percent of plants reaching maturity; 2) plant length (measured on main stem from the basis to plant extremity); 3) fruits number per plant scored at maturity on each individual plant per treatment; 4) fruits weight; 5) seeds number per fruit; 6) seeds weight per fruit; 7)100-seeds weight per fruit. Seeds were weighted at 5% moisture content.

Data were transformed (when appropriate) to achieve homogeneity of variance, using log(x+1) or arcsine for plant survival ratio (Dagnelie, 1998). For each parameter examined, one way analysis of variance was performed using the SAS statistical package (SAS, 2004). In case of a significant difference the Least Significant Difference (LSD) multiple range-tests were used to identify the means which differ (Dagnelie, 1998).

3. Results

Through both seasons, we recorded the same insect species but more damage occur in the second cropping season. Few insects were collected on the plots that were more frequently sprayed with insecticide as compared to the others. Most insects feeding injuries were observed on seedling, leaves, flowers, and fruits, in the untreated plots or when the insecticide applications stopped (50% seedling, 50% stem creeping) (Figure 1). The main damaging insects were represented by five species, including four beetles and one ladybird. The beetles include *Asbecesta cyanipennis* Harold, *Lilioceris livida* Dalman, *Aulacophora africana* Weise, and *Lamprocopa occidentalis* Weise (Coleoptera: Chrysomelidae) representing on average 40%, 28%, 19%, and 11%, of the insect pest collected, respectively. The damaging ladybird observed was *Henosepilachna elaterii* Rossi (Coleoptera: Coccinellidae), representing 2% of insect pests.

All the parameters measured except plant survival ratio (%), and plant length were significantly (P<0.001) influenced by the frequency of insecticide application during the first growing season (Table 3). The highest values of seeds yield (t ha^{-1}) and number of fruits per plant were obtained in the plots sprayed three times.

No significant difference in mean fruit weight was observed between three and four sprays treatment. The three parameters related to the seeds (seeds number per fruit, seeds weight per fruit and 100-seeds weight) had the highest values in plots treated two times.

In the second growing season, three traits (plant length, fruits number per plant and 100-seeds weight) were not significantly influenced by the frequency of insecticide application (P>0.05). Highly significant (P<0.001) differences were found between the five insecticide treatments for the seven remaining traits (Table 4). Only the plots sprayed four times were characterized by the highest mean values of seed yield (t ha^{-1}) and the three yield components related to the seeds.

To assess the results in relation to climatic parameters, means were calculated for each cropping season, regardless of the frequency of insecticide applications (Table 5). As indicated in Table 5, the highest values of seeds yield and all the yield components analyzed were obtained only in the first cropping season.

Table 3. Yield and yield components as affected by the frequency of insecticide application in the indigenous oilseed watermelon during the first growing season

Parameters	Insecticide application[a]					ANOVA results	
	Untreated control	One spray	Two sprays	Three sprays	Four sprays	*F*	*P*
Yield (t ha^{-1})	$0.32±0.08^{c}$	$0.40±0.10^{b}$	$0.55±0.20^{ab}$	$0.76±0.13^{a}$	$0.65±0.15^{ab}$	4.85	0.019
Plant survival ratio (%)	$93.33±11.55^{a}$	$96.67±11.55^{a}$	$100.00±0.00^{a}$	$97.78±3.85^{a}$	$100.00±0.00^{a}$	0.63	0.651
Plant length (m)	$3.96±1.10^{a}$	$3.86±1.15^{a}$	$4.31±0.98^{a}$	$4.34±0.89^{a}$	$4.32±1.19^{a}$	2.06	0.087
Fruits number $plant^{-1}$	$5.36±2.47^{c}$	$6.44±3.31^{bc}$	$6.05±2.83^{bc}$	$8.56±3.79^{a}$	$6.77±3.81^{b}$	5.66	0.002
Fruit weight (g)	$777.29±483.12^{d}$	$994.39±528.58^{c}$	$1107.08±537.80^{b}$	$1293.30±469.54^{a}$	$1342.93±372.89^{a}$	78.43	<0.001
Seeds number $fruit^{-1}$	$263.02±205.04^{c}$	$305.77±211.86^{b}$	$408.44±200.48^{a}$	$388.20±177.49^{a}$	$407.95±161.49^{a}$	35.67	<0.001
Seeds weight $fruit^{-1}$ (g)	$16.42±13.73^{b}$	$18.09±13.88^{b}$	$25.48±13.58^{a}$	$23.90±10.89^{a}$	$24.33±10.00^{a}$	32.83	<0.001
100-seeds weight (g)	$5.86±1.38^{b}$	$5.57±1.19^{b}$	$6.056±1.27^{ab}$	$6.19±1.24^{a}$	$6.07±1.11^{a}$	12.55	<0.001

[a]*Mean values within rows by parameter followed by the same superscripted letter were not significantly different at P = 0.05 level, on the basis of the Least Significant Difference (LSD) test*

Figure 1. Insect pests damages on seedling (A) adult plant (B) flower (C) and fruit (D) of the oilseed *Citrullus lanatus*

Table 4. Yield and yield components as affected by the frequency of insecticide application in the indigenous oilseed watermelon during the second growing season

Parameters	Insecticide application^{a}					ANOVA results	
	Untreated control	One spray	Two sprays	Three sprays	Four sprays	*F*	*P*
Yield (t ha^{-1})	0.10±0.05^{b}	0.12±0.04^{b}	0.15±0.06^{b}	0.22±0.03^{ab}	0.278±0.042^{a}	7.32	0.005
Plant survival ratio (%)	40.00±8.82^{c}	61.11±11.71^{b}	68.89±17.10^{b}	88.89±3.85^{a}	94.44±5.09^{a}	13.22	0.001
Plant length (m)	3.42±0.83^{a}	3.10±0.69^{a}	3.16±0.73^{a}	3.27±0.80^{a}	3.445±0.817^{a}	1.72	0.146
Fruits number plant^{-1}	5.07±2.41^{a}	3.74±2.07^{a}	4.13±2.55^{a}	4.07±1.94^{a}	4.483±1.853^{a}	1.87	0.117
Fruit weight (g)	801.57±371.64^{b}	679.21±339.01^{c}	752.39±360.24^{bc}	796.08±345.23^{bc}	912.241±449.098^{a}	11.77	<0.001
Seeds number fruit^{-1}	240.19±168.52^{c}	249.15±152.67^{c}	259.19±17.30^{c}	301.27±157.99^{b}	334.872±188.723^{a}	12.64	<0.001
Seeds weight fruit^{-1} (g)	13.58±10.17^{c}	13.71±9.28^{c}	14.51±9.80^{c}	16.45±9.20^{b}	18.924±11.820^{a}	11.58	<0.001
100-seeds weight (g)	5.57±1.08^{a}	5.41±0.95^{a}	5.60±1.00^{a}	5.45±0.98^{a}	5.62±1.05^{a}	1.19	0.108

[a]Mean values within rows by parameter followed by the same superscripted letter were not significantly different at P *= 0.05 level, on the basis of the Least Significant Difference (LSD) test*

Table 5. Yield and yield components as affected by the growing seasons in the indigenous oilseed watermelon

Parameters[a]	Season 1[b]	Season 2	ANOVA results	
			P	*F*
Yield (t ha^{-1})	0.54±0.20[a]	0.17±0.08[b]	77.04	<0.001
Plant survival ratio (%)	97.56±5.70[a]	70.67±22.19[b]	74.32	<0.001
Plant length (m)	4.16±1.08[a]	3.28±0.78[b]	104.58	<0.001
Fruits number $plant^{-1}$	6.64±3.43[a]	4.25±2.15[b]	85.54	<0.001
Fruit weight (g)	1132.83±516.61[a]	804.26±389.55[b]	337.40	<0.001
Seeds number $fruit^{-1}$	364.83±196.44[a]	287.52±174.57[b]	112.87	<0.001
Seeds weight $fruit^{-1}$ (g)	22.21±12.68[a]	16.02±10.43[b]	182.97	<0.001
100-seeds weight (g)	5.98±1.24[a]	5.53±1.02[b]	98.93	<0.001

[a]*Means per growing season were calculated independently of the frequency of insecticide application .*

[b]*Mean values within rows by parameter followed by the same superscripted letter were not significantly different at* P *= 0.05 level, on the basis of the Least Significant Difference (LSD) test .*

4. Discussion

Production inputs such as soil tilth and fertility, weed, plant pathogen, and pests management play major roles in determining the long-term suitability of production practices of any crop (Bruinsma *et al.*, 1983). The type and application method of pesticides are reported to be one of the most important production inputs affecting both yield amount and quality of several crops (Ignacimuthu & Jayaraj, 2003; Oerke & Dehne, 2004).

Since only the open pollinated cucurbit landraces are cultivated in Sub-Saharan Africa, the research of pests control strategies economically suitable and preventing the elimination of beneficial organisms (pest predators, pollinators, etc.) are prerequisites to enhance production.

On-farm monitoring of pest insect populations and the evaluation of their feeding injury as affected by frequency of the insecticide applications showed that leaf beetles are the most damaging in the oilseed *C. lanatus*. Indeed, significantly low values of yield and yield components were recorded in the control plots (without any chemical treatment), mainly due to four beetles and a ladybug. Striped cucumber beetle (*Acalymma vittatum*), spotted cucumber beetle (*Diabrotica undecimpunctat howardi*) and squash bugs (*Anasa tristis*) are reported to be the most serious pests on cucurbits in many production areas (Foster & Brust, 1995; Hoffmann *et al.*, 2000; Edelson *et al.*, 2003; Pair *et al.*, 2004). All the insects identified except *Lamprocopa occidentalis* are cucurbit-host-specific pests; the latter being also known to feed on rice in the study zone (Heinrichs & Barrion, 2004).

Results from this study indicated that seed yield and most of the yield components increased with an increasing number of sprays. Such a result could result from a better protection, allowing a better growth and development of *C. lanatus*. But, to our knowledge, there is no study addressing sustainable insecticide applications on cucurbits in the Sub-Saharan Africa, so it is difficult to relate our results to similar studies. Nevertheless, our results contrasted with those reported by Foster et al. (1995) from investigations carried out in Indiana (USA) using the dessert *C. lanatus*. Indeed, these found a significant negative correlation between the yield components and the number of sprays (R^2 e»0.05), suggesting that the yield decrease when the number of the insecticide application increase. This result has been attributed to the phytotoxicity and death or repulsion of pollinator insects, as Gusmini (2003) works concluded an appropriate population size of foraging insect (mainly bees) are required for ovule fertilization, and consequently for fruit set in watermelon. In our experiments, stopping the insecticide application at the female flower stage avoids killing the pollinators (Kevan, 1999; Palumbo *et al.*, 2001; Sharma & Abrol, 2005), and consequently prevent the yield from a decreasing.

The lowest yield observed in the season 2 could be attributed to the low temperature and the high amount of rainfalls during this period. Numerous authors reported that the foraging activity of bees that are the main pollinators of watermelon is reported to be negatively influenced by low temperature (Bacci *et al.*, 2006). In addition, rainfalls generally reduce the remanance of the contact pesticides. This is particularly frequent for the carbamate-based pesticides considered as highly toxic (Deparis, 2001) but easily leached by heavy rainfalls (Vallat *et al.*, 2005; Rose *et al.*, 2006). In this condition more plants could be damaged by the pest insects. The amount and distribution of rainfalls reported throughout the second growing season could also cause a high rate of flower drops. Such observations have been made on watermelon (Wang *et al.*, 2004) and cucumber (Bacci *et al.*, 2006). The total rainfall recorded 565 mm during the second season could have decreased the plant production, since watermelon is reported to be a low water requirement species (Wang *et al.*, 2004; Xie *et al.*, 2006). In China, the work of Xie et al. (2006) on supplemental drip irrigation of watermelon, showed that when a rainfall of 233 mm is suitably distributed throughout the growing period, a supplemental irrigation was not needed for watermelon production.

5. Conclusion

The use of the foliar carbamate-based insecticide (Cypercal EC 50) to control insect pests on the indigenous watermelon *Citrullus lanatus* was benefit. Since during both cropping seasons three or four applications increased yield and its components. Therefore, when rainfall and temperature are suitable in the target zone, we suggest three sprays (at seedling emergence, stem creeping, and male flower stage).

Acknowledgements

This research was financed by the Direction General de la Cooperation au Développement (DGCD, Brussels, Belgium) and supervised by the Comité Universitaire pour le Developpement (CUD, Brussels, Belgium). A scholarship to the first author was provided by the Scientific Research and High Education Ministry of the Côte d'Ivoire.

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