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Effect of Cyper-diforce® Application and Variety on Major Insect Pests of Watermelon in the Southern Guinea Savanna of Nigeria

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Abstract

In order to evaluate the inherent potentials of common watermelon varieties to withstand natural pest pressure and to identify potential sources of resistance for breeding programs, a 2-year field study was conducted in the research farm of Federal University Wukari, Nigeria in the early- and late-cropping seasons of 2016 and 2017. The experimental design was a 4 replicated Randomized Complete Block Design with split-plot arrangement of treatments in which main plots were synthetic insecticide (Cyper-diforce®) sprayed and unsprayed ones. The subplot treatments comprised of 5 watermelon commercial varieties namely; Charleston gray, Grey bell, Kaolack, Koloss F_1 and, Sugar baby (Kaolack; the most extensively cultivated variety in the study area was used as a standard for comparison). Kaolack and Koloss F_1, the more recently developed varieties, were observed to be better adapted as their growth were more prolific resulting to higher yields than other varieties. Across years and seasons, the major leaf-feeding beetles [*Aulacophora africana* (Weise), *Asbecesta nigripennis* (Weise), *Asbecesta transversa* (Allard), *Monolepta nigeriae* (Bryant), and *Epilachna chrysomelina* (Fabricius)]; sap-sucking insects [Aphid - *Aphis gossypii* (Glover) and whitefly - *Bemisia tabaci* (Gennadius)] and fruit feeding insects [african bollworm – *Helicoverpa armigera* (Hübner) and fruit fly – *Bactrocera cucurbitae* (Coquillett)] were significantly ($P < 0.0001$) more abundant in the unsprayed plots. Charleston gray, Grey bell and Sugar baby were more susceptible to leaf-feeding beetles but less susceptible to aphid, whitefly, african bollworm and fruit fly. The opposite was observed with Kaolack and Koloss F_1. Therefore, the newest variety (Koloss F_1) is recommended for cultivation in the study area as it produced higher yield. However, a further study is required to determine the mechanisms of resistance and their heritability to enable development of watermelon varieties with resistance to all the major insect pests.

Keywords: *Aphis gossypii* (Glover), Damage, *Helicoverpa armigera* (Hübner), Infestation, Insecticide application, Insect pests, *Monolepta nigeriae* (Bryant), Watermelon varieties.

1. Introduction

Watermelon, *Citrullus lanatus* Thunb. (Cucurbitaceae), is an economically important fruit vegetable crop cultivated in most regions of the world (Adeoye *et al.*, 2011). It has high health, nutritional benefits, and return on investment (Ajewole, 2015). Leaf feeding beetles such as *Aulacophora africana* (Weise), *Asbecesta nigripennis* (Weise), *Asbecesta transversa* (Allard), *Monolepta nigeriae* (Bryant), *Phyllotreta cruciferae* (Goeze) [Coleoptera: Chrysomelidae]; *Epilachna chrysomelina* (Fabricius) [Coleoptera: Coccinellidae]; Sap sucking insects such as Aphid [*Aphis gossypii* (Glover) (Hemiptera: Aphididae)] and Whitefly [*Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae)] and, Fruit feeding insects such as African bollworm [*Helicoverpa armigera* (Hübner) (Lepidoptera, Noctuidae)] and Fruit fly [*Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae)] have been reported to infest the crop in different parts of the world and particularly, across different agro-ecological zones of Nigeria (Ogunlana, 1996; Bamaiyi *et al.*, 2010; Burabai *et al.*, 2011; Souza *et al.*, 2012; Lima *et al.*, 2014; Okrikata *et al.*, 2019). Except those who could not afford, watermelon farmers in Nigeria and specifically across the Southern Guinea Savanna Zone depend almost entirely on synthetic insecticides for insect pest control - which are largely applied indiscriminately (Okrikata and Ogunwolu, 2017). Although synthetic insecticides have been found to be effective to a reasonable extent, many health, environmental and economic related challenges have been associated with their usage.

The majority of the documented watermelon varieties worldwide are cultivated in Africa (Yakubu *et al.*, 2018). Though most of the farmers in the study area cultivate the variety "Kaolack" popularly called "*Mai Yashi*" - in Hausa language primarily due to its accessibility and market value/customer demand (Okrikata and Ogunwolu, 2017), it is very important to recognize the role morphological and/or physiological differences among varieties can play in influencing crop damage by insect pest. Available literature, however, indicates that while many watermelon varieties have varying levels of resistance to some pathogens, there is rarely such well known and/or well documented information with respect to insect pest

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infestation (Department of Agriculture, Forestry and Fisheries, 2011).

Planting a variety that is not suited for the available market and the particular production situation leads to lower profits or possibly crop failure. In addition, a variety must have acceptable yield and the highest level of pest resistance and such information are useful in breeding programs. There is, however, very little empirically based documented report on relative performance of watermelon varieties exposed to natural insect pest infestation. This study was designed to bridge these knowledge gaps.

2. Materials and Methods

2.1. Study Site

The study was carried out on the experimental farm of Federal University Wukari, Nigeria (N7º50'37", E9º46'31" and 187m altitude), which lies within the Nigerian southern guinea agro-ecological zone [it is characterized by a warm tropical climate with distinct wet and dry seasons - the wet season commences in April and ends in October with June and September being the peak months (Okrikata and Yusuf, 2016)] during 2016 and 2017 early- and late-planting seasons (planting dates: May 14th and August 23rd in 2016 and May 10th and August 15th in 2017).

2.2. Study Design

The experimental design was a Randomized Complete Block Design (RCBD) with split plot arrangement of treatments replicated 4 times. The main plot treatments were 0.5 % Cypermethrin 30g/L + Dimethoate 250g/L EC (Cyper-diforce®) sprayed - maximum of 3 times at each crop growth stage at weekly interval and unsprayed plots. Subplot (subplot size: 5m long, 8m wide) treatments were 5 commercial varieties of watermelon; namely Charleston gray, Grey bell, Kaolack, Koloss F_1 and, Sugar baby. Kaolack variety, popularly called in Hausa language "*Mai yashi*", was the most extensively cultivated variety in the study area largely due to seed accessibility and consumer acceptability/market value (Okrikata and Ogunwlu, 2017) and was therefore used as a standard for comparison in the current study.

2.3. Data Collection

2.3.1. Sampling and Assessment of Insect Pest Population

Sampling of leaf feeding beetles predominated by *Aulacophora africana* (Weise), *Asbecesta nigripennis* (Weise), *Asbecesta transversa* (Allard), *Monolepta nigeriae* (Bryant) [chrysomelidae] and *Epilachna chrysomelina* (Fabricius) [coccinellidae] commenced at 70 % emergence stage (2 weeks after planting - WAP) and proceeded at weekly intervals until fruit maturity. Collection was made between 16:00 and 18:00h using a shoulder mounted motorized suction sampler (Burkard Scientific Ltd., Uxbridge, UK) with a 10 cm diameter inlet cone swept through 5 m length of the middle row at an approximate walking speed of 1 m/sec. The mean population of the insects was computed as number/5 m length of row.

Sampling of sap sucking insects predominated by hemipterous *Aphis gossypii* (Glover) and *Bemisia tabaci* (Gennadius) commenced at the vegetative stage of the crop (3 WAP) and proceeded at weekly intervals till crop maturity. For *A. gossypii*, estimates of population density was made by assessing the colony size on 12 randomly selected leaves/plot, using a scale of **0** – **5** scale, where: **0** = no aphids; **1** = 1 – 4 aphids; **2** = 5 – 20 aphids; **3** = 21 – 100 aphids; **4** = 101 – 500 aphids and **5** = > 500 aphids modified after Egho (2011). For *B. tabaci*, a 15 x 15 cm yellow sticky board was waved across the 5 m length of the middle row of each subplot on shaking the plants therein and the insects trapped were counted as described by Anaso (1999).

The major fruit feeding pests were *Bactrocera cucurbitae* (Coquillett) [Diptera: Tephritidae] and *Helicoverpa armigera* (Hübner) [Lepidoptera: Noctudae]. Larvae of *B. cucurbitae* (fruit fly) were sampled at harvest in which case infested fruits were isolated and counted in each plot. They were split open and the number of *B. cucurbitae* larvae therein counted and expressed as number/fruit using the formula described by Barma *et al*. (2013):

$$\text{No. of } \textit{B. cucurbitae} \text{ larvae/fruit} = \frac{\text{No. of infested fruits x No. of larvae per infested fruit}}{\text{No. of fruits per plot}}$$

However, sampling of *H. armigera* larvae commenced at mid-flowering stage (6 WAP) using the suction sampler and following the method used for sampling leaf feeding beetles as described above.

2.3.2. Identification of Insect Pest

Samples of dominant insects collected were killed in ethyl acetate in a killing jar and then preserved in 70% ethanol. Moths were dried and preserved in an airtight container containing silica gel. Immature stages were reared to adult in the laboratory for identification. The insects were all identified at the insect museum of Institute of Agricultural Research (IAR), Ahmadu Bello University Zaria, Nigeria.

2.3.3. Assessment of Leaf Injury and Growth Parameters

At 3, 6 and 9 WAP, a random sample of 15 leaves/subplot was taken and the proportion damaged was recorded. The leaves were also scored for severity of injury on a scale of **0** – **4**, following the method described by Trusca *et al.* (2013) where:

0 = 0 % leaf area injured
1 = 1 – 25 % leaf area injured
2 = 26 – 50 % leaf area injured
3 = 51 – 75 % leaf area injured
4 = 76 - 100 % leaf area injured.

The individual scores obtained per subplot were converted to attack severity (%) using the equation described by Okrikata and Anaso (2008):

$$\text{Attack severity (\%)} = \sum n \text{ x } 100/N \text{ x } 4$$

Where; $\sum n$ = summation of individual injury scores/plot, N = number of scores taken/plot (= 15), and4 = highest score on the scale.

Also, at 9 WAP, 3 plants were randomly selected per subplot from which the main vine length (cm) was measured with a flexible tape and the average number of lateral and secondary branches computed.

2.3.4. Evaluation of Fruit Yield

Fruits in each subplot were harvested twice at 10 days interval, weighed, and sorted into marketable and unmarketable categories. The latter comprised of fruits that were discolored, misshapen, cracked, insect damaged, and infected with blossom end rot. The proportion of the marketable fruits was computed.

2.4. Data Analysis

Numerical data was transformed to $\sqrt{x + 0.5}$ while data in percentages transformed to arcsine before variance analysis. Significantly, different treatment means were separated by Students Newman Keul's (SNK) test at 5 % level of probability using SAS statistical software, version 9.2.

3. Results

3.1. Effect of Chemical Treatment and Variety on Major Insect Pests of Watermelon

Across years and seasons, the major leaf-feeding beetles (*A. africana, A. nigripennis, A. transversa, M. nigeriae* and *E. chrysomelina*) were significantly ($P < 0.0001$) more abundant in the unsprayed plots (Table 1). The most common was *A. nigripennis* followed by *M. nigeriae*. The least was *E. chrysomelina*. Charleston gray variety consistently attracted more beetles followed by Sugar baby. Kaolack variety had the least beetle density followed by Koloss F_1 in both early- ($P < 0.0001$) and late-sown ($P = 0.6399$) crops of 2016. Corresponding probability values for 2017 cropping year were (0.0373 and < 0.0001), respectively. The interaction between synthetic chemical insecticide (Cyper-diforce®) application (C) and variety (V) in 2016 cropping year was significant ($P < 0.001$) in the early-sown but not ($P = 0.7621$) in the late-sown. Corresponding p-values for 2017 cropping year were 0.3107 and < 0.001, respectively.

Density of *A. gossypii* was 67.2 % ($P < 0.0001$) higher in the unsprayed than sprayed plots of the early-sown crop of 2016 cropping year and correspondingly 460.5 % in the late-sown. In 2016 early-sown crop, Charleston gray had significantly ($P < 0.0001$) the least infestation while Kaolack, the highest. Grey bell, Sugar baby and Koloss F_1 had statistically comparable infestation level. In the late-sown, however, Charleston gray and Sugar baby varieties had significantly ($P < 0.0001$) lower and comparable infestation while Kaolack and Koloss F_1 had higher. Interaction effect was significant in the early- ($P < 0.0001$) and insignificant in the late- ($P = 0.1648$) sown crops. A similar trend in *A. gossypii* infestation was observed in 2017 early- and late-crop, respectively, except that interaction effect was significant ($P < 0.05$) in both. Tables 2a and b reveal that infestation by *B. tabaci* follows a trend similar to that of *A. gossypii*. Insecticide application reduced infestation by 24.5 and 39.6 % (in the early- and late-sown crop of 2016) and correspondingly by 5.7 and 35.2 % in 2017. Across years and seasons, differences among varieties were significant ($P < 0.05$) with Kaolack and Koloss F_1 varieties having higher infestations and, Charleston gray and Sugar baby, lower and interaction effects consistently insignificant ($P > 0.05$).

Tables (3a and b) revealed that *B. cucurbitae* density was 5-fold higher in the unsprayed than in the sprayed early-sown crop of 2016; on the late-sown, differential was 10-fold ($P < 0.0001$). In 2017, the differentials were approximately 4 and 9-folds, respectively. In both the early- and late-sown crops of 2016, the density of *B. cucurbitae* larvae per fruit was significantly ($P < 0.0001$) higher in Kaolack, followed by Koloss F_1 than in Charleston gray and Sugar baby varieties. Differences among varieties in 2017 trials followed a somewhat similar trend with interaction effects across years and seasons being significant ($P < 0.0001$). *H. armigera* infestation was rare on the early-crop of both years. However, it was predominant on late-crops with trends in infestation among varieties following a trend similar to that of *B. cucurbitae* in both years except for the insignificant interactions ($P > 0.05$) between insecticide application and variety (Tables 3a, b).

3.2. Effect of Chemical Treatment and Variety on Leaf Injury of Watermelon

In all the trials, the proportion and severity of leaf injury was significantly ($P < 0.0001$) higher on unsprayed than on sprayed crops. Sugar baby and Charleston gray had significantly ($P < 0.0001$) more proportions of leaves injured with a higher severity of leaf injury than the other varieties. Kaolack had the lowest proportion of leaves injured and severity, followed by Koloss F_1. Interaction between insecticide application and variety were consistently insignificant ($P > 0.05$) for both parameters across years and seasons (Tables 4a and b).

3.3. Effect of Chemical Treatment and Variety on Growth of Watermelon

In 2016, insecticide treatment significantly ($P < 0.001$) increased main vine length by 148.2 and 149.3 % in the early- and late-sown crops, respectively (Table 5a). Varieties differed significantly ($P < 0.0001$) with Sugar baby having the longest main vine length and Grey bell having the shortest. With respect to the number of lateral branches, an increase of 161.8 and 160.9 % due to insecticide treatment in the early- and late-sown crops respectively was observed. Generally, Kaolack, Charleston gray and Koloss F_1 produced more lateral branches ($P < 0.0001$) than Grey bell and Sugar baby in both early- and late-sown crops. Insecticide treatment resulted in significantly increased ($P < 0.0001$) number of secondary branches by 2.8 X in each of the early- and late-sown crop. Koloss F_1 and Kaolack were statistically comparable and both were significantly ($P < 0.0001$) different from the other varieties in the number of secondary branches produced in both early- and late-sown crops. Interaction was significant ($P < 0.05$) for both early- and late-sown crops for main vine length, number of lateral branches and number of secondary branches. A somewhat similar trend was observed in 2017 cropping year (Table 5b).

3.4. Effect of Chemical Treatment and Variety on Fruit Yield of Watermelon

With respect to marketable fruit yield, sprayed plots were observed to be > 240-fold more productive (tha^{-1}) than unsprayed plots in 2016 cropping year. Charleston gray and Sugar baby were statistically comparable in the early- as well as in the late-sown crops. From these 2, the remaining 3 varieties were significantly different. They were significantly different one from another as well with Koloss F_1 being the most productive. Interactions between insecticide application and variety were significant ($P < 0.0001$). A similar trend was observed in 2017 cropping year (Table 6).

Table 1. Effects of insecticide application and variety on abundance (Mean±SE) of major leaf-feeding beetles in early- and late-sown watermelon varieties in Wukari.

	Leaf-feeding beetles collected/5m length of row[1]			
	2016 cropping year		2017 cropping year	
Treatment	Early-sown[2]	Late-sown[2]	Early-sown[2]	Late-sown[2]
Chemical treatment (C)				
Sprayed (0.5 % cyper-diforce®)	$2.83{\pm}0.11^{b}$	$1.23{\pm}0.04^{b}$	$2.89{\pm}0.21^{b}$	$1.28{\pm}0.05^{b}$
Un-sprayed (0 % cyper-diforce®)	$21.16{\pm}0.39^{a}$	$10.88{\pm}0.22^{a}$	$23.76{\pm}2.45^{a}$	$11.11{\pm}0.25^{a}$
P value	<0.0001	<0.0001	<0.0001	<0.0001
Variety (V)				
Kaolack	$10.62{\pm}3.10^{e}$	$5.36{\pm}1.62^{a}$	$10.77{\pm}3.14^{b}$	$5.48{\pm}1.65^{e}$
Charleston gray	$13.43{\pm}3.77^{a}$	$6.89{\pm}2.01^{a}$	$19.38{\pm}8.02^{a}$	$6.95{\pm}2.05^{a}$
Grey bell	$11.88{\pm}3.45^{c}$	$5.93{\pm}1.79^{a}$	$12.07{\pm}3.50^{ab}$	$6.06{\pm}1.83^{c}$
Sugar baby	$12.89{\pm}3.65^{b}$	$6.57{\pm}1.96^{a}$	$13.08{\pm}3.70^{ab}$	$6.71{\pm}1.99^{b}$
Koloss F_1	$11.13{\pm}3.36^{d}$	$5.63{\pm}1.74^{a}$	$11.32{\pm}3.40^{b}$	$5.75{\pm}1.78^{d}$
P value	<0.0001	ns	0.0373	<0.0001
Interaction				
C x V	***	ns	ns	***

[1]Means (±SE) of Aulacophora africana, Asbecesta nigripennis, Asbecesta transversa, Monolepta nigeriae and Epilachna chrysomelina.

[2] Means are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test (P ≤ 0.05); * = significantly different (P ≤ 0.05); ** = significantly different (P ≤ 0.01); *** = significantly different (P ≤ 0.001); ns = not significantly different (P > 0.05).

Table 2a. Effects of insecticide application and variety on abundance (Mean±SE) of major sap-sucking insects in early- and late-sown watermelon in Wukari in 2016.

	***Aphis gossypii* score**		***Bemisia tabaci***	
Treatment	**Early-sown[1]**	**Late-sown[1]**	**Early-sown[1]**	**Late-sown[1]**
Chemical treatment (C)				
Sprayed (0.5 % cyper-diforce®)	$1.19{\pm}0.02^{b}$	$0.81{\pm}0.05^{b}$	$13.90{\pm}0.29^{b}$	$23.52{\pm}0.79^{b}$
Un-sprayed (0 % cyper-diforce®)	$1.99{\pm}0.07^{a}$	$4.54{\pm}0.12^{a}$	$17.31{\pm}0.39^{a}$	$32.84{\pm}0.96^{a}$
P value	<0.0001	<0.0001	<0.0001	<0.0001
Variety (V)				
Kaolack	$1.90{\pm}0.22^{a}$	$3.14{\pm}0.78^{a}$	$17.12{\pm}0.84^{a}$	$31.97{\pm}2.15^{a}$
Charleston gray	$1.35{\pm}0.09^{c}$	$2.29{\pm}0.62^{c}$	$14.33{\pm}0.60^{c}$	$25.57{\pm}2.01^{b}$
Grey bell	$1.57{\pm}0.15^{b}$	$2.63{\pm}0.73^{b}$	$15.53{\pm}0.81^{bc}$	$27.64{\pm}2.15^{b}$
Sugar baby	$1.56{\pm}0.15^{b}$	$2.40{\pm}0.65^{bc}$	$14.39{\pm}0.77^{c}$	$24.76{\pm}1.96^{b}$
Koloss F_1	$1.57{\pm}0.15^{b}$	$2.93{\pm}0.77^{a}$	$16.66{\pm}0.70^{ab}$	$30.95{\pm}1.74^{a}$
P value	<0.0001	<0.0001	<0.0001	<0.0001
Interaction				
C x V	***	ns	ns	ns

[1]Means are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \leq 0.05$); * = significantly different ($P \leq 0.05$); ** = significantly different ($P \leq 0.01$); *** = significantly different ($P \leq 0.001$); ns = not significantly different ($P > 0.05$)

Table 2b. Effects of insecticide application and variety on abundance (Mean±SE) of major sap-sucking insects in early- and late-sown watermelon in Wukari in 2017.

	***Aphis gossypii* score**		***Bemisia tabaci***	
Treatment	**Early-sown[1]**	**Late-sown[1]**	**Early-sown[1]**	**Late-sown[1]**
Chemical treatment (C)				
Sprayed (0.5 % cyper-diforce®)	$2.22{\pm}0.01^{b}$	$2.74{\pm}0.11^{b}$	$11.01{\pm}0.23^{b}$	$27.13{\pm}0.81^{b}$
Un-sprayed (0 % cyper-diforce®)	$4.02{\pm}0.06^{a}$	$3.36{\pm}0.15^{a}$	$11.64{\pm}0.24^{a}$	$36.67{\pm}0.98^{a}$
P value	<0.0001	<0.0001	0.0372	<0.0001
Variety (V)				
Kaolack	$3.30{\pm}0.39^{a}$	$3.67{\pm}0.17^{a}$	$12.25{\pm}0.30^{a}$	$35.79{\pm}2.20^{a}$
Charleston gray	$2.96{\pm}0.30^{d}$	$2.42{\pm}0.10^{c}$	$10.53{\pm}0.26^{b}$	$29.23{\pm}2.06^{b}$
Grey bell	$3.12{\pm}0.35^{c}$	$3.05{\pm}0.12^{b}$	$11.59{\pm}0.36^{ab}$	$31.35{\pm}2.20^{b}$
Sugar baby	$3.00{\pm}0.31^{d}$	$2.43{\pm}0.10^{c}$	$10.60{\pm}0.26^{b}$	$28.39{\pm}2.01^{b}$
Koloss F_1	$3.22{\pm}0.37^{b}$	$3.67{\pm}0.15^{a}$	$11.64{\pm}0.39^{ab}$	$34.75{\pm}1.78^{a}$
P value	<0.0001	<0.0001	0.0029	<0.0001
Interaction				
C x V	<0.0001	0.0006	ns	ns

[1]Means are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \leq 0.05$); * = significantly different ($P \leq 0.05$); ** = significantly different ($P \leq 0.01$); *** = significantly different ($P \leq 0.001$); ns = not significantly different ($P > 0.05$)

Table 3a. Effects of insecticide application and variety on abundance (Mean±SE) of major fruit-feeding insects in early- and late-sown watermelon in Wukari in 2016.

Treatment	Early-sown[1] *Bactrocera cucurbitae* larvae/fruit	Late-sown[1] *Bactrocera cucurbitae* larvae/fruit	*Helicoverpa armigera* larvae/5m row
Chemical treatment (C)			
Sprayed (0.5 % cyper-diforce®)	4.62±0.20[b]	0.83±0.13[b]	4.64±0.23[b]
Un-sprayed (0 % cyper-diforce®)	21.40±0.72[a]	8.17±0.30[a]	9.23±0.03[a]
P value	<0.0001	<0.0001	<0.0001
Variety (V)			
Kaolack	15.60±3.97[a]	5.55±1.73[a]	8.09±0.94[a]
Charleston gray	11.19±2.63[d]	3.72±1.04[c]	6.11±0.93[bc]
Grey bell	13.13±3.27[c]	4.62±1.45[b]	6.58±0.84[b]
Sugar baby	11.26±2.68[d]	3.80±1.17[c]	5.72±0.85[c]
Koloss F_1	13.88±3.36[b]	4.79±1.46[b]	8.16±0.92[a]
P value	<0.0001	<0.0001	<0.0001
Interaction			
C x V	***	***	ns

[1]Means (±SE) are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \le 0.05$); * = significantly different ($P \le 0.05$); ** = significantly different ($P \le 0.01$); *** = significantly different ($P \le 0.001$); ns = not significantly different ($P > 0.05$)

Table 3b. Effects of insecticide application and variety on abundance (Mean±SE) of major fruit-feeding insects in early- and late-sown watermelon in Wukari in 2017.

Treatment	**Early-sown[1]** ***Bactrocera cucurbitae*** **larvae/fruit**	**Late-sown[1]** ***Bactrocera cucurbitae*** **larvae/fruit**	***Helicoverpa armigera*** **larvae/5m row**
Chemical treatment (C)			
Sprayed (0.5 % cyper-diforce®)	5.72±0.10[b]	0.86±0.03[b]	6.61±0.23[b]
Un-sprayed (0 % cyper-diforce®)	23.18±0.74[a]	8.34±0.31[a]	11.14±0.30[a]
P value	<0.0001	<0.0001	<0.0001
Variety (V)			
Kaolack	17.15±4.13[a]	5.68±1.76[a]	10.02±0.93[a]
Charleston gray	12.55±2.74[d]	3.81±1.16[c]	8.06±0.92[bc]
Grey bell	14.58±3.40[c]	4.74±1.48[b]	8.52±0.83[b]
Sugar baby	12.63±2.78[d]	3.89±1.20[c]	7.68±0.84[c]
Koloss F_1	15.35±3.50[b]	4.91±1.49[b]	10.09±0.91[a]
P value	<0.0001	<0.0001	<0.0001
Interaction			
C x V	***	***	ns

[1]Means (±SE) are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \le 0.05$); * = significantly different ($P \le 0.05$); ** = significantly different ($P \le 0.01$); *** = significantly different ($P \le 0.001$); ns = not significantly different ($P > 0.05$).

Table 4a. Effects of insecticide application and variety on leaf injury in early- and late-sown watermelon in Wukari in 2016.

Treatment	**Mean proportion of leaves injured (%)** **Early-sown[1]**	**Late-sown[1]**	**Mean severity of leaf injury (%)** **Early-sown[1]**	**Late-sown[1]**
Chemical treatment (C)				
Sprayed (0.5 % cyper-diforce®)	17.51±1.55[b]	16.63±1.49[b]	7.15±0.62[b]	6.83±0.59[b]
Un-sprayed (0 % cyper-diforce®)	66.86±3.28[a]	64.66±2.70[a]	46.45±0.90[a]	45.24±0.70[a]
P value	<0.0001	<0.0001	<0.0001	<0.0001
Variety (V)				
Kaolack	33.17±9.17[b]	31.67±8.70[c]	24.38±7.50[c]	23.53±7.26[b]
Charleston gray	50.24±11.65[a]	48.04±11.10[a]	27.74±7.04[ab]	28.15±7.17[a]
Grey bell	43.06±8.55[a]	40.11±7.95[ab]	26.35±7.60[bc]	25.46±7.35[b]
Sugar baby	50.65±11.17[a]	48.59±10.72[a]	29.95±7.78[a]	28.60±7.44[a]
Koloss F_1	37.28±8.08[b]	34.80±8.13[bc]	25.58±7.55[bc]	24.62±7.27[b]
P value	<0.0001	<0.0001	0.0019	0.0003
Interaction				
C x V	ns	ns	ns	ns

[1]Means (±SE) are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \le 0.05$); ns = not significantly different ($P > 0.05$).

Table 4b. Effects of insecticide application and variety on leaf injury in early- and late-sown watermelon in Wukari in 2017.

	Mean proportion of leaves injured (%)		Mean severity of leaf injury (%)	
Treatment	**Early-sown[1]**	**Late-sown[1]**	**Early-sown[1]**	**Late-sown[1]**
Chemical treatment (C)				
Sprayed (0.5 % cyper-diforce®)	21.66±1.19[b]	21.66±1.27[b]	8.01±0.69[b]	7.97±0.69[b]
Un-sprayed (0 % cyper-diforce®)	72.33±2.50[a]	69.22±2.64[a]	53.58±0.81[a]	52.41±0.84[a]
P value	<0.0001	<0.0001	<0.0001	<0.0001
Variety (V)				
Kaolack	37.78±9.02[c]	36.39±8.54[c]	27.86±8.63[b]	27.13±8.36[b]
Charleston gray	53.89±11.51[a]	52.50±11.20[a]	33.04±8.47[a]	32.61±8.32[a]
Grey bell	46.94±8.37[b]	45.27±7.75[b]	30.08±8.70[b]	29.34±8.46[b]
Sugar baby	54.16±11.06[a]	53.05±0.69[a]	33.84±8.83[a]	33.37±8.67[a]
Koloss F_1	42.22±8.65[bc]	39.99±7.86[bc]	29.16±8.66[b]	28.50±8.42[b]
P value	<0.0001	<0.0001	0.0003	0.0002
Interaction				
C x V	ns	ns	ns	ns

[1]Means (±SE) are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \leq 0.05$); ns = not significantly different ($P > 0.05$).

Table 5a. Effects of insecticide application and variety on main vine length and number of branches in early- and late-sown watermelon in Wukari in 2016.

	Main vine length at 9 WAP (cm)		Number of lateral branches at 9 WAP		Number of secondary branches at 9 WAP	
Treatment	**Early-sown[1]**	**Late-sown[1]**	**Early-sown[1]**	**Late-sown[1]**	**Early-sown[1]**	**Late-sown[1]**
Chemical treatment (C)						
Sprayed[2]	309.11±3.81[a]	329.26±4.31[a]	4.53±0.29[a]	4.54±0.36[a]	38.68±3.93[a]	40.62±4.21[a]
Un-sprayed[3]	124.54±1.91[b]	132.06±2.06[b]	1.73±0.13[b]	1.74±0.25[b]	13.58±1.26[b]	14.28±1.33[b]
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Variety (V)						
Kaolack	216.77±34.87[c]	230.77±36.89[c]	3.54±0.78[a]	3.56±0.88[a]	36.16±9.12[a]	38.30±8.78[a]
Charleston gray	213.57±36.57[d]	228.33±39.81[d]	3.41±0.62[a]	3.49±0.62[a]	14.28±3.17[c]	14.94±3.31[b]
Grey bell	196.92±31.12[e]	208.10±32.97[e]	2.28±0.37[b]	2.29±0.47[b]	18.16±2.88[bc]	18.96±3.01[b]
Sugar baby	232.58±36.78[a]	246.86±39.49[a]	2.52±0.50[b]	2.53±0.60[b]	24.40±3.80[b]	25.68±3.96[b]
Koloss F_1	224.28±34.78[b]	239.26±37.21[b]	3.90±0.64[a]	3.91±0.77[a]	37.65±6.00[a]	39.38±7.36[a]
P value	<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001
Interaction						
C x V	***	***	*	*	**	**

[1]Means (±SE) are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \leq 0.05$); [2]Sprayed - (0.5 % cyper-diforce®); [3]Un-sprayed - (0 % cyper-diforce®)

* = significantly different ($P \leq 0.05$); ** = significantly different ($P \leq 0.01$); *** = significantly different ($P \leq 0.001$).

Table 5b. Effects of insecticide application and variety on main vine length and number of branches in early- and late-sown watermelon in Wukari in 2017.

	Main vine length at 9 WAP (cm)		Number of lateral branches at 9 WAP		Number of secondary branches at 9 WAP	
Treatment	**Early-sown[1]**	**Late-sown[1]**	**Early-sown[1]**	**Late-sown[1]**	**Early-sown[1]**	**Late-sown[1]**
Chemical treatment (C)						
Sprayed[2]	296.91±3.47[a]	332.67±4.22[a]	4.48±0.28[a]	4.50±0.38[a]	37.88±3.85[a]	39.15±3.80[a]
Un-sprayed[3]	129.17±1.74[b]	139.42±2.06[b]	1.72±0.14[b]	1.73±0.23[b]	13.30±1.23[b]	14.01±1.30[b]
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Variety (V)						
Kaolack	219.82±31.61[b]	244.47±36.46[b]	3.51±0.77[a]	3.88±0.64[a]	35.41±8.94[a]	37.72±5.69[a]
Charleston gray	210.09±33.50[d]	233.76±39.01[d]	3.37±0.62[a]	3.38±0.72[a]	17.78±2.82[bc]	14.64±3.25[c]
Grey bell	194.95±28.28[e]	213.94±32.31[e]	2.51±0.49[b]	2.27±0.26[b]	13.99±2.10[c]	18.58±2.95[bc]
Sugar baby	227.36±33.42[a]	251.92±38.70[a]	2.26±0.36[b]	2.51±0.59[b]	23.90±3.72[b]	25.17±3.87[b]
Koloss F_1	212.99±31.69[c]	236.15±36.16[c]	3.86±0.63[a]	3.52±0.87[a]	36.86±6.86[a]	36.78±8.99[a]
P value	<0.0001	<0.0001	0.0004	<0.0001	<0.0001	<0.0001
Interaction						
C x V	***	***	*	*	**	**

[1]Means (±SE) are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \leq 0.05$); [2]Sprayed - (0.5 % cyper-diforce®); [3]Un-sprayed - (0 % cyper-diforce®)

* = significantly different ($P \leq 0.05$); ** = significantly different ($P \leq 0.01$); *** = significantly different ($P \leq 0.001$).

Table 6. Effects of insecticide application and variety on fruit yield/ha in early- and late-sown watermelon in Wukari, cropping years 2016 and 2017,

	Marketable fruit yield (tha^{-1})			
	2016		**2017**	
Treatment	**Early-sown[1]**	**Late-sown[1]**	**Early-sown[1]**	**Late-sown[1]**
Chemical treatment (C)				
Sprayed (0.5 % cyper-diforce®)	39.87±2.49[a]	45.76±2.73[a]	38.41±2.41[a]	44.16±2.93[a]
Un-sprayed (0 % cyper-diforce®)	0.15±0.02[b]	0.19±0.02[b]	0.11±0.01[b]	0.14±0.08[b]
P value	<0.0001	<0.0001	<0.0001	<0.0001
Variety (V)				
Kaolack	23.45±8.79[b]	26.70±10.01[b]	22.61±9.50[b]	25.73±9.66[b]
Charleston gray	13.48±5.14[d]	15.70±5.94[d]	12.97±4.96[d]	15.11±5.77[d]
Grey bell	19.77±7.50[c]	22.80±8.60[c]	19.02±7.21[c]	21.94±8.35[c]
Sugar baby	15.42±5.82[d]	17.97±6.85[d]	14.81±5.60[d]	17.33±6.66[d]
Koloss F_1	27.92±10.49[a]	31.71±11.88[a]	26.90±10.13[a]	30.63±11.55[a]
P value	<0.0001	<0.0001	<0.0001	<0.0001
Interaction				
C x V	***	***	***	***

[1]Means (±SE) are values of four replications; Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \leq 0.05$); *** = significantly different ($P \leq 0.001$)

4. Discussion

Results obtained show vulnerability of watermelon varieties to insect pest damage as reported by Gichimu *et al*. (2008) and that effective protection against insect pests of watermelon is necessary for meaningful yield in the study area. The insecticide used (Cyper-diforce®) is a mixture of Cypermethrin 30g/L and Dimethoate 250g/L EC. Cypermethrin is a broad-spectrum, neurotoxic, contact synthetic pyrethroid, while Dimethoate is a widely used systemic organophosphate insecticide that interferes with nerve impulse transmission in arthropods (Cox, 1996; Qayoom *et al*., 2016). The choice of cyper-diforce® insecticide is apt as it has the ability of suppressing both chewing and sap sucking insects, and the results obtained indicates that it was significantly effective in managing all the major insect pests of watermelon.

Recommending a variety most suitable to an agro-ecological zone requires using common varieties in the area for performance trial. None of the varieties tested in the current trials exhibited resistance to all the major insect pests of watermelon. While Charleston gray, Sugar baby and Grey bell had relatively higher infestation by leaf-eating beetles and lower infestation by aphid (*A. gossypii*), whitefly (*B. tabaci*), African bollworm (*H. armigera*) and fruit fly (*B. cucurbitae*), Kaolack and Koloss F_1 had higher infestation by aphid, whitefly, African bollworm and fruit fly and lower infestation by leaf-eating beetles. A number of studies have shown that different varieties/genotypes of the same plant species could respond significantly differently to different insect pests (Simmons *et al.*, 2010; Haldhar *et al*., 2015). These differences may be attributed to differences in biochemical and/or morphological traits.

Attractiveness of chrysomelid beetles to cucurbits (watermelon, inclusive) had been linked to higher cucurbitacin content (Gichimu *et al*., 2009). This is said to be due to the co-evolutionary relationship between cucurbits and luperine chrysomelid beetles (Metcalf and Lampman, 1989). At the same time, cucurbitacin has been linked to protection against herbivory by other insect pests other than the luperine chrysomelid beetles (Koul *et al*., 2008). The results obtained in this study suggest that Charleston gray, Sugar baby and Grey bell which were developed well over half a century ago (1954, 1956 and 1963, respectively) may contain higher cucurbitacin and hence were more attractive to chrysomelid beetles and resistant to other major pests - aphids, whiteflies, African bollworm and fruit flies. Kaolack and Koloss F_1 are comparatively recently developed varieties and may have been selected for much lower cucurbitacin [cultivated cucurbits have been selected over time for lower amounts of cucurbitacins as a result of their toxicity and bitterness (Recio *et al*., 2012)] and higher yields. The trade-off is such that, lower cucurbitacin implies lesser beetle infestation and higher infestation by other major pests of watermelon.

The ability of leaf eating beetles to weaken seedlings and/or bring about loss of plant stands resulting to yield loss has been shown by Kemble *et al*., (2005). Leaf injury has also been shown to have serious implication on the quantity and quality of fruits produced by watermelon plants as the leaves play a key role in synthesizing sugar and accumulating water in the fruits (Nath, 2002). This implies that the higher the proportion and/or intensity of leaf injury, the lower the quality and/or quantity of fruits produced. Such trend was observed in the present study as Kaolack and Koloss F_1 which had lesser proportion and intensity of leaf injury had higher fruit yields. Of the 5 dominant leaf feeding beetles, *A. nigripennis* followed by *M. nigeriae* were more common. The least common was *E. chrysomelina.* Since the leaf feeding beetles have largely similar pattern of injury on the crop leaves, it was difficult to mention which species of them was most harmful. Therefore, their relative abundance indicates their relative harmfulness on the crop.

Though, the impacts of the major sap-sucking pests (*A. gossypii* and *B. tabaci*) were difficult to estimate on the field, the negative effect of their infestation on growth and yield cannot be ruled out. Throughout the 2 years research, occurrence of *H. armigera* (a fruit feeding insect) in the early-season was sporadic, which may be attributed to unfavorable weather conditions – increased frequency and intensity of rainfall. However, its effect (along with *B. cucurbitae*) in reducing the marketability of the fruits was very obvious.

The higher yields of Kaolack and Koloss F_1 relative to the other varieties could be attributed to lower infestation and damage by leaf-feeding beetles, higher survival rate, more prolific growth evidenced by longer vine length and more lateral and secondary branches. Gichimu *et al*. (2008) reported an association between prolific growth and high yield of watermelon. The current information on variable response by watermelon varieties to major insect pests could be useful for watermelon breeding programs.

5. Conclusion

Koloss F_1, the more recently developed variety, was better adapted and its growth more prolific producing higher yields than other varieties except, Kaolack. Charleston gray, Grey bell and Sugar baby, which were more susceptible to leaf-eating beetles, were less than aphid, whitefly, African bollworm and fruit fly. The opposite was observed with Kaolack and Koloss F_1. A further study is, therefore, recommended to determine the mechanisms of resistance and their heritability to enable development of commercially acceptable watermelon variety with better resistance to the major insect pests and higher yields.

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References

Adeoye IB, Olayide–Tawo FB, Adebisi–Adelan O, Usman JM, and Badmus MA. 2011. Economic analysis of watermelon based production system in Oyo State. *Nig J Agric Biol Sci.*, **6(7)**: 53-59.

Ajewole OC. 2015. Income analysis of watermelon production in Ekiti State, Nigeria. *J Econs Sus Dev.*, **6(2)**: 67-72.

Anaso CE. 1999. Evaluation of Neem Extracts for Control of Major Insect Pests of Okro (*Abelmoschus esculentus*) Ph.D. Thesis. University of Maiduguri. 131pp.

Bamaiyi LJ, Alao SEL, and Amans E. 2010. Optimum sprays required for insect pest management on rain-fed watermelon. Horticultural Crop Research Programme, Cropping Scheme Reports. IAR, ABU, Zaria. February, 23 – 24, 2010. Pp 33–35.

Barma P, Jha S, and Banerjee S. 2013. Prediction of population development of melon fruit-fly (*Bactrocera cucurbitae* Coquillett) on Pionted Gourd (*Trichosanthes dioica* Roxb.). *Afri J Agric Res.*, **8(38):** 4740–4747.

Burabai W, Etekpe GW, Ambah B, and Angaye PE. 2011. Combination of garlic extract and some organophosphate insecticides in controlling Thrips (*Thrips palmi*) in Watermelon. *Int J Appl Sci Eng.*, **9(1)**: 19–23.

Cox C. 1996. Insecticide factsheet: Cypermethrin. *J Pes Ref.*, **16(2):** 15 – 20.

Department of Agriculture, Forestry and Fisheries. 2011. **Production guidelines: Watermelon (*Citrullus lanatus*)**. Compiled by Directorate of Plant Production, Pretoria, South Africa. 32pp.

Egho EO. 2011. Management of major field insect pests and yield of cowpea (*Vigna unguiculata* (L.)Walp) under calendar and monitored application of synthetic chemicals in Asaba, Southern Nigeria. *Am J Sci Indus Res.*, **2(4)**: 592–602.

Gichimu BM, Owuor BO, and Dida MM. 2008. Assessment of four commercial watermelon cultivars and one local landrace for their response to naturally occurring disease, pests and non-pathogenic disorders in sub-humid tropical conditions. *J Agric Biol Sci.*, **3(5 and 6)**: 32–43.

Gichimu BM, Owuor BO, Mwai GN, and Dida MM. 2009. Morphological characterization of some wild and cultivated watermelon (*Citrullus* sp.) accession in Kenya. *J Agric Biol Sci.*, **4(2)**: 10-18.

Haldhar SM, Choudhary BR, Bhargava R, and Meena SR. 2015. Antixenosis and allelochemical resistance traits of watermelon against Bactrocera cucurbitae in a hot arid region of India. *Flor Entomol.*, **98(3):** 827-834.

Kemble JM, Sikora EJ, Patterson MG, Zehnder GW, and Buske E. 2005. Guide to commercial summer squash production. Alabama Cooperative Extension System. Alabama A and M University and, Auburn University. PubID: 1014.

Koul O. 2008. Phytochemicals and insect control: An antifeedant approach. *Crit Rev Plant Sci.*, **27**: 1 – 24.

Lima CHO, Sarmento RA, Rosado JF, Silveira MCAC, Santos GR, Pedro-Neto M, Erasmo EAL, Nascimento IR, and Picanço MC. 2014. Efficiency and economic feasibility of pest control systems in watermelon cropping. *J of Econ Entomol.*, **107(3)**: 1118–1126.

Metcalf RL, and Lampman RL. 1989. The chemical ecology of diabroticites and cucurbitaceae. *Experentia*, **45**: 240–247.

Nath P, Sundari P, and Singh DP. 2002. Vegetables for the Tropical Region. Indian Council of Agricultural Research, New Delhi. 420pp.

Ogunlana MO. 1996. Insect pests of watermelon *Citrullus lanatus* in Samaru Zaria. Research Programmes Reports (1995 – 1996) of Institute of Agricultural Research, Ahmadu Bello University Zaria. Pp.171–172.

Okrikata E, Ogunwolu EO, and Ukwela MU. 2019. Diversity, spatial and temporal distribution of above-ground arthropods associated with watermelon in the Nigerian Southern Guinea Savanna. *J Insect Biod Syst.*, **5(1)**: 11–32.

Okrikata E, and Yusuf OA. 2016. Diversity and abundance of insects in Wukari, Taraba State, Nigeria. *Intl Biol Biomed J.*, **2(4)**: 156–166.

Okrikata E, and Ogunwolu EO. 2017. Farmers' perceptions on arthropod pests of watermelon and their management practices in the Nigerian Southern Guinea Savanna. *Int J Agric Res.*, **12(4)**: 146–155.

Okrikata E, and Anaso CE. 2008. Influence of some inert diluents of neem kernel powder on protection of sorghum against pink stalk borer (*Sesamia calamistis,* Homps) in Nigerian Sudan Savanna. *J Plant Protec Res.*, **48(2)**: 161–168.

Qayoom I, Shah FA, Mukhtar M, Balkhi MH, Bhat FA, and Bhat BA. 2016. Dimethoate induced behavioural changes in juveniles of *Cyprinus carpio* var. communis under temperate conditions of Kashmir, India. *The Sci World J.*, Article ID 4726126, http://dx.doi.org/10.1155/2016/4726126.

Recio MC, Andujar I, and Rios JL. 2012. Anti-inflammatory agents from plants: Progress and potential. *Curr Med Chem.,* **19**: 2088–2103.

Simmons AM, Kousik CS, and Levi A. 2010. Combining reflective mulch and host plant resistance for sweetpotato whitefly (Hemiptera: Aleyrodidae) management in watermelon. *Crop Protec.,* **29:** 898-902.

Souza CR, Sarmento RA, Venzon M, Barros EC, Santos GR, and Chaves CC. 2012. Impact of insecticides on non-target arthropods in watermelon crop. *Ciências Agrárias*, **33(5)**: 1789–1802.

Trusca R, Grozea I, and Stef R. 2013. Attractiveness and injury levels of adults by *Diabrotica virgifera virgifera* (Le Conte) on different host plant. *J Food Agric Environ.*, **2(3 and 4)**: 773–776.

Yakubu VA, Salifu A, Moses KAM, and Ibrahim NI. 2018. Means of transportation of watermelon (*Citrullus lanatus* [Thunb.]) fruit within the Tamale Metropolis in the Northern Region of Ghana. *J Biol Agric Healthcare*, **8(4)**: 50–59.