Evaluation of control methods for fruit flies (Diptera: Tephritidae) on watermelon (C*itrullus lanatus* (Thumb.) Matsum. & Nakai) in The Gambia

Running title: Fruits, *Dacus vertebratus*, insecticides, baits, insect pests, management

ABSTRACT

Commercial production of watermelon (*Citrullus lanatus* (Thunb.) Matsum & Nakai) is increasing in The Gambia, but tephritid fruit flies present a huge challenge to its production. To avoid severe losses, watermelon growers often resort to indiscriminate use of pesticides to manage the pest. Field studies were conducted at two sites (Faraba and Site 3) in the West Coast Region of The Gambia to evaluate two environmentally friendly options (Success Appat (GF-120) and Cocoa Butter Cream) for management of fruit flies on the crop. Dimethoate insecticide, the farmers' preferred choice, was used as a chemical check whilst untreated control plots were also maintained. The field plots were arranged in Randomized Complete Block Design and the treatments were replicated three times. The results of the study showed that, even though three species of fruit flies, *Bactrocera dorsalis* (Hendel)*, Dacus vertebratus* Bezzi and *Zeugodacus cucurbitae* Coquillett were collected at both study sites, only *D*. *vertebratus* infested watermelon fruits. Both Success Appat (GF-120) and Cocoa Butter Cream reduced watermelon fruit infestation and, generally, provided comparable protection to watermelon fruits against fruit flies as the check (Dimethoate) and therefore would be suitable replacements.

1. INTRODUCTION

Watermelon (*Citrullus lanatus* (Thunb.) Matsum & Nakai) is one of the crops grown on commercial basis in The Gambia. Its production is becoming increasingly commercialized and currently, it is one of the major sources of income for farmers. As a horticultural crop, its commercial production is as a result of high export value, high yield and returns per unit area [1]. In The Gambia, usually, the crop is cultivated towards the end of the rainy season but many farmers start production when the rains begin. The fruit is mostly consumed in fruit salads or as dessert. Some farmers sell their fruits to hotels whiles a few export them to Senegal. According to [2], the drought conditions which occurred in 2002 in the Sahel (which includes The Gambia) and late onset of rains prompted farmers to shift to cultivate short cycle crops such as watermelon and sesame.

The production of watermelon faces many challenges but the most important among these, is the fruit flies menace. Fruit flies attack young succulent fruits in the field and can cause considerable damage. Watermelon is a highly perishable fruit and suffers significant damage during its transportation and distribution as well as at points of vending as a result of poor handling. Losses in yield due to fruit flies' infestation of watermelon fruits are quite high in The Gambia. Several species of fruit flies (Diptera: Tephritidae) are invasive pests of horticultural crops worldwide, due to their adaptation to various regions, high polyphagia and rapid reproduction [3] Important fruit fly species in The Gambia include, *Bactrocera dorsalis* (Drew and Hancock), *Bactrocera cucurbitae* (Coquillett), *Dacus cucurbitae* (Coquillett), *Ceratitis corsyra* (Walker) and *Dacus vertebratus* (Bezzi).

As a consequence of severe damage caused by fruit flies, watermelon growers often resort to the use of synthetic insecticides to protect their fields from the time of fruit setting to harvest. Such treatments are effective, but the volume of imported horticultural produce into countries free of these pests raises biosecurity concerns [4]. In The Gambia, some farmers spray their watermelon fields with insecticides up to 2 or 3 days before harvest. [5] reported that apart from resistance development by insect pests, several synthetic insecticides, that are commonly used by farmers to reduce pest' damage to the crop, can produce both human health and environmental problems. In addition, given the dependence of fruit fly

distribution and abundance on climate variables, there are also concerns about the intensification of the climate changes that will facilitate the occurrence of more frequent outbreaks in horticultural regions [6]. So, [7] advocated the use of integrated pest management (IPM) approach, which offers more economic benefits to farmers while improving food safety and minimizing risk to human health and the environment.

In order to minimize the use of synthetic pesticides, environmentally friendly control methods of fruit flies should be tested and promoted for use by watermelon farmers. Products such as Success Appat (GF-120), which is a food bait (insect attractant) for control of fruit flies, and Cocoa Butter Cream (body cream), which has proven to be attractive to fruit flies, should be tested for their effectiveness against fruit flies in watermelon fields. In this context, both environmentally friendly products, Success Appat and Cocoa Butter Cream, were evaluated for their suitability for the management of fruit flies in watermelon production. The aims of this study were to determine, i. the diversity and abundance of fruit fly species attacking watermelon fruits in The Gambia, and ii. the effectiveness of Success Appat and Cocoa Butter Cream for fruit flies' management in watermelon production.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in The Gambia, lying between latitudes 13^{o} and 14^{o} North and longitudes 17^{o} and 12^{o} West. The study involved both field and laboratory work and was undertaken in 2018. Two sites were used during fieldwork. The fields were located on the campus of the New University of The Gambia in Faraba in the Kombo East District (N13^{0} 14.909' W16^{0} 32.062' with an elevation of 23 m.a.s.l and at the National Agricultural Research Institute (NARI) Site 3 Research field at Bunjulinding (N13^{0} 22.171' W16^{0} 38.858' with an elevation of 95 m.a.s.l) in the Kombo North District of West Coast Region of The Gambia. Laboratory work was conducted at the Biocontrol laboratory of the Plant Protection Services of The Gambia, located in Yundum Agricultural Station, West Coast Region. There is only one rainy season in a year in The Gambia which occurs from June up to October. Watermelon production is mostly done towards the end of the rains between August and October.

2.2 Land preparation and sowing of seeds

The land at each site was ploughed and harrowed. The seeds were sown directly into the soil at three to four seeds per hole and later thinned to one per stand two weeks after germination. The spacing used was 1.5 m between rows and 1 m between plants. Sowing was done on 3rd September 2018 at Faraba and on 8th October 2018 at Site 3 to stagger between the two sites. The fields were cleared of weeds, with hoes, two weeks after sowing after which hand pulling of weeds was done bi-weekly.

2.2.1 Soil analysis

Soil samples from the two study sites were collected using auger, mixed, bulked separately and dried. These samples were sent to the Soil Science laboratory of the Department of Crop and Soil Sciences of Kwame Nkrumah University of Science and Technology (KNUST), Ghana for analysis.

2.2.2 Fertilizer Application

Compound fertilizer NPK 15:15:15 was applied to seedling two weeks after emergence and top-dressed with Urea 46%, by a broadcast application of 1.5 kg of NPK and 0.75 kg of Urea per plot at a rate of 200 kg/ha for NPK and 100 kg/ha for Urea.

2.3 Experimental Design

The experimental fields were laid out in Randomized Complete Block Design (RCBD). For this purpose, the total research field area for each location, measuring 46 m by 26.5 m, was subdivided into four treatment plots of 10 m by 7.5 m (75 m^2), which in turn were separated with alleys of 2 m between the plots. There were five rows of plants in each plot with a planting distance of 1.5 m between rows and 1 m between plants. Data were collected from the three middle rows of each treatment plot.

2.3.1 Treatments

Four treatments were performed for the present study, and consisted of: Success Appat® (GF-120) (T1), Cocoa Butter Cream (T2), Dimethoate, as a chemical control (T3), and an absolute control, i.e. without product application (T4). The details of the treatments are provided in Table 1. Each plot received a single treatment, and each treatment was replicated three times.

Table 1: Treatments employed in two different watermelon, *Citrullus lanatus*, test fields in The Gambia

Treatment	Product (ml or g)	Water (ml)	v/v (Ratio) (ml)
Success Appat ® (GF-120)	7.5	37	1:5
Cocoa Butter Cream	5	0	Pure
Dimethoate Insecticide	4.5	750	1:167 applied at a rate of 600 ml/ha (4.5 ml of Dimethoate into 750 ml of water using a Knapsack sprayer.
Control	0	0	No product applied

2.3.2 Treatment ratio composition and application method

A hand sprayer of 2 l capacity was used to apply the Success Appat® (GF-120) and a Knapsack sprayer of 16 l was used to apply Dimethoate insecticide to allow an effective application of the two different spray solutions. The Cocoa Butter cream was applied using water bottles of 1.5 l as traps which contained the Cream and DDVP strip killing agents. Treatment applications were done from 1st October to 5th November, 2018 for Faraba and 5th November to 10th December, 2018 for Site 3.

The Succes Appat® (GF-120) was applied at a ratio of 1: 5 v/v (see Table 1 for more details). The solution obtained in the handheld sprayer was thoroughly mixed by shaking and delivered on spots at 1 m^2 on foliage till the leaves were wet. The spraying was done carefully to get the underside of leaves and also avoid the fruits. Border vegetation and some shrubs that were not removed during the second weeding within the plots were also sprayed. Spraying was done between 16.00 and 18.00 h in almost still breeze to avoid drift. The GF-120 was applied weekly for five weeks beginning at 50 % flowering.

2.3.3 Cocoa Butter Cream Traps

Constituents of Princess Diana Cocoa Butter Cream with Karitea (Abidjan, Cote d'Ivoire), are: Stearic acid, mineral oil, EDTA, water, lanolin, trielanolamine, cocoa butter, glycerin and fragrance. This cream is readily available in cosmetic shops in The Gambia. A cotton wool, obtained from a Banjul pharmacy, was tied with thread into a small roll weighing 2 g. Tying was done to make the rolls firm and last longer. About 5 g of Cocoa Butter Cream was smeared on the cotton rolls until they were uniformly covered. Homemade 1.5 l empty mineral bottle traps were used. The bottle traps were made using a sharp knife to

cut two rectangular holes measuring 6 cm by 4 cm on opposite sides of the bottle. Binding wires, of 1 m in length, were used to create a hole on the bottle covers by heating the tip of the wires using fire. About 15 cm of the wire was pushed through the holes on the cover. Then, the wire was coiled and bent to enable it to both hang the bottles and hook the cotton wool with the thread. The bottle covers were tightened and a strip of Dichlorvos (DDVP) insecticide was placed in the bottles as killing agent. These traps were hanged at a height of 1 m from the ground on sticks planted in the plots. Only plots labelled for this treatment received these traps. A total of four traps were placed in each plot at a spacing of 4 m by 6 m. The Cocoa Butter Ceam was replaced every seven days (weekly), while the DDVP strips were changed after four weeks of use to ensure that did they not lose their killing potency. The traps were set in the watermelon field area for five weeks.

Dimethoate insecticide was applied at the recommended dose rate of 600 ml per hectare, at a ratio of 1:167 v/v per plot, on a weekly basis (See Table 1). Separate measuring cylinders were used to measure both the water and insecticide. The water was first poured into the knapsack followed by the insecticide and shaken to mix the solution well. The solution was applied uniformly to the treatment plot area and carefully done to avoid spray drift. Application of the insecticide was discontinued two weeks before harvesting of fruits as recommended on the label. Similarly, application of the other treatments (GF-120 and Cocoa Butter Cream Traps) was discontinued two weeks before harvesting to observe the recommended pre-harvest interval.

As stated previously, control plots did not receive any treatment products.

2.4. Data collection

2.4.1 Monitoring of fruit fly species presence

The presence of fruit flies in the study site was monitored prior to the commencement of application of treatments. This was done using two different slow release disperser attractants, Methyl Eugenol (ME) and Cuelure (CU) and DDVP strips used as killing agents placed in McPhail tephritidae traps (Russell IPM Ltd, Unit 45 First Avenue, Zone 2 Deeside Industrial Park, Deeside, Flintshire, CH5 2NU, United Kingdom) (www.russellipm.com). Four traps were used separately for each treatment. The traps were set at four points on the edges of the field at opposite locations with each point having one ME and one CU

trap. The traps at each point were placed 3 m apart on sticks at 1 m above the ground. Monitoring of fruit flies' adults was done on a weekly basis for three weeks; it covered the periods 10th September to 1st October 2018 at Faraba and 15th October to 5th November 2018 at Site 3. The samples were collected in labelled plastic vials and carried to the laboratory, counted and identified. All fruit flies adults' catches were stored in 70% ethanol in a dark place to avoid losing their identification features. The total fruit fly numbers were recorded and the number of flies per trap per day (fly density, i.e. FTD index) was determined using the formula:

$$\text{Fly Density} = \frac{F}{T \times D}$$

Where F= Total number of flies collected

T= Number of Traps

D= Number of days traps were set in the watermelon field

(Source: [3, 4])

2.4.2 Cocoa Butter Cream trap effectiveness

Fruit flies attracted and killed inside the Cocoa Butter Cream traps were collected weekly into labelled plastic vials for each plot. The catches were counted in the laboratory before identifying them to species and sex. The densities of the flies were determined as indicated previously. The catches were stored in 70% ethanol in a dark place to avoid losing their identification features.

2.4.3 Fruit sampling, maintenance, and pupae retention

Watermelon fruits were sampled from the two study sites after three to four weeks of chemical application. Samples were collected from the three middle rows in each treatment. The fruits were placed in labeled sampling bags and carried to the laboratory.

Sand from the Senegambia beach was collected and washed thoroughly to remove the saline content, sieved to remove foreign materials, spread to dry and then sterilized at 120^0 C for at least three hours to kill pathogens. The sand was then spread inside buckets used as pupation chambers. The temperature and relative humidity levels maintained in the room were 25 ± 2^oC and 65 ± 10%, respectively. The sampled fruits were weighed in the laboratory and separately placed on wire gauze for suspension from

the pre-sterilized sand inside the incubation chambers. This suspension of the fruits was necessary to enable developed larvae to drop into the soil beneath which served as the pupation medium. Each of the buckets used as incubation chamber was labelled with the chemical used to treat the plot. The sand in the incubation chambers was sieved to collect puparia that fell within 3-4 days' intervals. Incubation was done from 29th October to 19th November 2018 for Faraba and from 3rd to 24th December 2018 for Site 3. Incubated fruits were finally dissected after three weeks to check for any remaining larvae or pupa before disposal. From the sampled fruits, the percentage of fruit infestation and the puparia number for each treatment were recorded in order to determine the efficacy of treatments.

2.4.3.1 Emergence of adult flies

The collected puparia from the incubated fruits were placed on moist filter papers in Petri dishes and conditioned into cubical cages measuring 20 cm x 20 cm x 20 cm. The puparia in the cages were monitored for any emerged flies. After emergence, adult flies were fed with adult flies' diet prepared with 1 part of Baker's instant yeast and 3 parts of sugar. Water was supplied into the cages for the flies inside pots with cotton wool inserted in them through a hole in the cover. The emerged flies were fed, *ad libitum*, for a week to develop their identification features. After one week the flies were killed by cold. The number of flies from each cage was counted before identification.

2.5 Identification of fruit flies

The trap catches and the emerged insects from the incubation were identified using fruit flies' identification guides, prepared by the West African Mango Fruit Fly Project, and taxonomic keys, developed by the African Fruit Fly Initiative (AFFI), [3]. The results of the identification were recorded in the fruit fly trapping data collection sheet.

2.6 Harvesting of fruits

After seven weeks of treatment application, mature fruits were harvested and weighed. Harvesting started on 19th November, 2018 for Faraba and 24th December, 2018 for Site 3. Harvesting was done from the three middle rows of each plot for two weeks at 3 to 4 days intervals and yield estimated by taking the

weight of harvested fruits in the plot. The yield was recorded in tons per hectare by extrapolating the weight of the harvested fruits in the plot area to a hectare.

2.20 Data analysis

Field data were subjected to ANOVA using GENSTAT 12 Edition. Insect count data were transformed using square root transformation to stabilize variances whiles data in percentages were arc-sin transformed for same purpose. Followed means were separated using Tukey's HSD test at 5% significance level.

3. RESULTS

3.1 Soil analysis for Faraba and Site 3

The soil analysis showed that the soil at Faraba is predominantly sandy with a pH of 6.76 whilst that of Site 3 is predominantly sandy loam soil with a pH of 6.86. Faraba soil had less nutrients and organic matter than Site 3 (Table 2).

Table 2: Soil analysis report for Faraba and Site 3, The Gambia

SAMPLE NAME (SOIL)	pH	AVAIL P(mg/kg)	% TOTAL N	Exch. Bases (cmol/kg)				Exch. Acidity (cmol/kg)		% Org. Carbon	% Org. Matter
				K	Ca	Mg	Na	Al	H		
SITE 3	6.86	5.017	0.0602	0.129	2.60	1.40	0.006	0.177	0.14	1.476	2.545
FARABA	6.76	4.177	0.0378	0.095	1.60	1.00	0.002	0.174	0.16	0.758	1.307

SOIL TEXTURE

SAMPLE ID	% SAND	% CLAY	% SILT	TEXTURE CLASS
SITE 3	70.112	3.440	26.450	SANDY LOAM
FARABA	88.112	1.312	10.580	SAND

3.2 Pre-treatment monitoring

During the monitoring in Faraba, 1521 fruit flies were captured in 21 days out of which 1507 were *Bactrocera dorsalis* and 7 each were *Dacus vertebratus* and *Zeucodacus cucurbitae*. All the *Bactrocera*

dorsalis species were captured in Methyl Eugenol traps while the Cuelure traps captured both *Dacus vertebratus* and *Zeucodacus curcubitae* (Table 3).

Table 3: Summary of fly catches in Methyl Eugenol (ME) and Cuelure (CL) baited traps at Faraba, The Gambia, during the first three weeks after sowing.

Point	Fruit fly species	No. of flies	Exposure period (Days)	Flies/Trap/Day
1 (ME)	*B. dorsalis*	230	21	10.95
1 (CU)	*D. vertebratus*	2	21	0.09
1 (CU)	*Z. cucurbitae*	3	21	0.14
2 (ME)	*B. dorsalis*	237	21	11.28
2 (CU)	*D. vertebratus*	2	21	0.09
2 (CU)	*Z. cucurbitae*	0	21	0.00
3 (ME)	*B. dorsalis*	515	21	24.52
3 (CU)	*D. vertebratus*	2	21	0.09
3 (CU)	*Z. cucurbitae*	3	21	0.14
4 (ME)	*B. dorsalis*	525	21	25.0
4 (CU)	*D. vertebratus*	1	21	0.04
4 (CU)	*Z. cucurbitae*	1	21	0.04

At Site 3, the number of fruit flies captured was 211 in 21 days, out of which 184 were *Bactrocera dorsalis* and 9 and 18, respectively, were *Dacus vertebratus* and *Zeugodacus cucurbitae*. Similarly, the *B. dorsalis* were all captured in the Methyl eugenol baited traps whiles the Cuelure traps captured *D. vertebratus* and *Z. cucurbitae* (Table 4).

Table 4: Summary of fly catches with Methyl Eugenol (ME) and Cuelure (CL) baited traps at Site 3, West Coast Region of The Gambia, during the first three weeks after sowing

Point	Fruit fly species	No. of flies	Exposure period (Days)	Flies/Trap/Day
1 (ME)	*B. dorsalis*	48	21	2.28
1 (CU)	*D. vertebratus*	2	21	0.09
1 (CU)	*Z. cucurbitae*	3	21	0.14

2 (ME)	*B. dorsalis*	39	21	1.85
2 (CU)	*D. vertebratus*	0	21	0.0
2 (CU)	*Z. cucurbitae*	8	21	0.38
3 (ME)	*B. dorsalis*	48	21	2.28
3 (CU)	*D. vertebratus*	3	21	0.14
3 (CU)	*Z. cucurbitae*	3	21	0.14
4 (ME)	*B. dorsalis*	49	21	2.33
4 (CU)	*D. vertebratus*	4	21	0.19
4 (CU)	*Z. cucurbitae*	4	21	0.19

3.3 Number of puparia recovered from incubated fruits from Faraba and Site 3

At Faraba, significant differences (P<0.05) were observed between treatment 4 (control) and the other treatments but there was no significant difference between GF-120, Cocoa Butter Cream and Dimethoate in terms of the number of puparia collected from the sample fruits during incubated fruits (Table 5). At Site 3, significant differences (P<0.05) existed between all the treatments. The lowest number of puparia was recorded from the dimethoate-treated plots and the highest from the control plots (Table 5).

Table 5.: Mean number of puparia in watermelon fruits from Faraba and Site 3, The Gambia

	Number of Puparia	
Treatment	**Faraba**	**Site 3**
Success Appat ® (GF-120)	50.7 b	64.3 c
Cocoa Butter Cream	52.0 b	102.7 b
Dimethoate Insecticide	42.0 b	39.7 d
Control	164.7 a	154.3 a
CV (%)	8.0	2.5

Means with the same letter in the column are not significantly different, according to Tukey HSD test at *P*<0.05

3.4 Number of puparia per kilogram of sampled fruit from Faraba

At Faraba, there were at least 70% reduction in infestation in GF-120, Cocoa Butter Cream and Dimethoate treated plots as compared to the control (Table 6).

Table 6: Mean fruit weight, number of puparia and infestation level of 12 watermelon fruits from the different treatments at Faraba, The Gambia

Treatment	Wt. of fruits (kg)	No. of Puparia	Infestation level (Pupae/kg)	Diff	% Reduction
Success Appat ® (GF-120)	21.52	152	7.06	20.54	74.4
Cocoa Butter Cream	18.94	156	8.23	19.37	70.1
Dimethoate Insecticide	19.36	126	6.50	21.10	76.4
Control	17.89	494	27.60		

Diff = difference between the infestation level of the control and that of other treatments

3.5 Number of puparia per kilogram of sampled fruit from Site 3

At Site 3, the highest (76.5%) reduction in infestation was recorded in Dimethoate treated plots while the lowest (39.5%) reduction in infestation was recorded in Cocoa Butter Cream treated plots as compared to the control (Table 7).

Table 7: Mean fruit weight, number of puparia and infestation level of 12 watermelon fruits from the different treatments at Site 3, The Gambia.

Treatment	Wt. of fruits (kg)	No. of Puparia	Infestation level (pup/kg)	Diff	% Reduction
Success Appat ® (GF-120)	28.11	193	6.86	13.16	65.7
Cocoa Butter Cream	25.44	308	12.10	7.92	39.5
Dimethoate Insecticide	25.29	119	4.70	15.32	76.5
Control	23.16	464	20.03		

Diff – Difference between infestation level of the Control and the that of any other treatment

3.6 Number of emerged adults from Faraba and Site 3, The Gambia

At Faraba, there was significant difference ($P<0.05$) between the control plot and the rest of the treatments with respect to the number of adult flies that emerged from the puparia. No significant

differences were observed between the GF-120, Cocoa Butter Cream and Dimethoate insecticide treatments (Table 8). At Site 3, there were no significant differences (P>0.05) between the control, GF-120 and Cocoa Butter Cream treated plots, and similarly, there were no significant differences observed between GF-120, Cocoa Butter Cream and Dimethoate insecticide treated plots.

Table 8: Number of emerged adults from watermelon fruits at Faraba and Site 3, The Gambia

	Number of emerged adults	
Treatment	**Faraba**	**Site 3**
SUCCESS Appat ® (GF-120)	6.1 b	6.8 ab
Cocoa Butter Cream	5.3 b	7.7 ab
Dimethoate Insecticide	4.7 b	3.9 b
Control	11.5 a	9.5 a
CV (%)	8.2	2.9

Means with the same letter in the column are not significantly different, according to Tukey test at *P*<0.05

3.7 Weight of watermelon fruits from Faraba and Site 3, The Gambia

At both Faraba and Site 3, there were no significant differences (P>0.05) among treatments in terms of the weight of fruits (Table 9).

Table 9: Weight of watermelon fruits per plot at Faraba and Site 3, The Gambia

	Weight of fruits (g)	
Treatment	**Faraba**	**Site 3**
Success Appat ® (GF-120)	1794 a	2343 a
Cocoa Butter Cream	1578 a	2120 a
Dimethoate Insecticide	1614 a	2108 a
Control	1491 a	1930 a
CV (%)	12.6	11.8

Number of fruits sampled (n) = 12 for each treatment

3.8 Cocoa Butter Cream Trap effectiveness at Faraba and Site 3, The Gambia

Cocoa Butter creamtrap treatments in Faraba captured 632 fruit flies in 35 days, all of which were *Dacus vertebratus* species, with a mean catch of 6.0 flies/trap/day. However, at Site 3, the Cocoa Butter Cream

trap captured 826 fruit flies in 35 days, all of which were again, *Dacus vertebratus* species and a mean catch of 7.9 flies/trap/day.

3.9 Fruit yield (t/ha) from Faraba and Site 3, The Gambia

At Faraba, there were no significant differences between the GF-120, Dimethoate and control treatments in terms of fruit yield. Similarly, no significant differences existed between Cocoa Butter Cream and Dimethoate treated plots; however, significant differences ($P<0.05$) existed between Cocoa Butter Cream treatment regarding GF-120 and the control plots (Table 10).

At Site 3, significant difference ($P<0.05$) in yield was observed between the control and the rest of the treatments, with the control plots recording the smallest yields. There were no significant differences between GF-120 treated and Cocoa Butter treated-plots and also between GF-120 and Dimethoate treated plots. However, the largest watermelon yields were obtained from Dimethoate-treated plots (Table 10).

Table 10: Watermelon fruit yield (t/ha) from Faraba and Site 3, The Gambia

	Yield (t/ha)	
Treatment	**Faraba**	**Site 3**
SUCCESS Appat ® (GF-120)	28.5 b	56.5 ab
Cocoa Butter Cream	42.2 a	53.8 b
Dimethoate Insecticide	32.0 ab	69.9 a
Control	23.6 b	34.1 c
CV (%)	13	9.1

Means with the same letter in the column are not significantly different, according to Tukey test at $P<0.05$

4. DISCUSSION

The soil analysis results indicated that the soil at Faraba was sandy and that of Site 3 was sandy loam. The sandy soil at Faraba may have contributed to the lower yields obtained because sandy soils generally are known to be poor in nutrients and organic matter and therefore need improvement, both physically and chemically for good crop production. Both locations had soil pH ranges recommended for watermelon production. According to a previous study, [9] watermelons grow best on well drained, slightly

acidic sandy loam soils and can fairly tolerate a soil pH as low as 5.5 but grow best in soil pH between 6.0 and 7.0.

The results of this study show that fruit flies are a real threat to watermelon production in The Gambia. Aside from watermelon, fruit flies attack other fruit crops including mango and citrus, as well as vegetables. Moreover, the present study reports that *Dacus vertebratus* is the main fruit fly species attacking watermelon in The Gambia. In addition, Cocoa Butter Cream was an effective attractant to fruit flies that could be used in an integrated management strategy for this main pest. During the monitoring of fruit flies, larger numbers of *Bactrocera dorsalis* were captured at both locations (Faraba and Site 3). Finally, it is surprising that no adults of *B*. *dorsalis* and *Z. cucurbitae* species were recovered from infested watermelon fruit as previous work had listed them as pests of the crop [10, 11].

The results of the study at both Faraba and Site 3 showed that application of all three treatments (GF-120, Cocoa Butter Cream and Dimethoate Insecticide) reduced fruit fly infestation of watermelon. The effectiveness of insecticides for the control of fruit flies has been previously demonstrated by other researchers. For instance, [12] reported that when different products were sprayed on infested cherries, numbers of live fruit fly larvae in fruit after eight days were smaller in imidacloprid and thiacloprid treatments, and these two performed better than spinosad and spinosad bait treatments. In a similar study, [13] reported that GF-120 was not effective at low dosages. They explained that fruit flies may have visited other fields for food before colonizing treated plots or may have laid eggs before spot treatment application, rendering the contact product less effective. It should be noted that GF-120 label explains that the product works better when applied over a large area instead of spot application.

Cocoa Butter Cream treated traps were found to capture only *D*. *vertebratus* species all of which were males. It is interesting to note that, in contrast, [14] reported that there were no fruit fly captures in the Beauty cream traps set in their study. The constituents of the Beauty Creams may explain the difference in effectiveness of attracting the flies. Generally, the import of the result of the present study is that Cocoa Butter Cream is less effective against other fruit flies especially *B*. *dorsali*s which was captured more in this study and currently the most important fruit fly species in the West Africa sub-region. Further, it

means that the cream does not attract female fruit flies that cause damage to the fruits through their oviposition punctures. The cream may be more useful for the suppression of fruit fly population when used in Male Annihilation Technique. It can be argued that, in order to obtain good protection from Cocoa Butter Cream application in the field, the product should be applied when initial monitoring confirms the presence of *Dacus vertebratus*.

Both GF-120 and Cocoa Butter Cream treated plots reduced the level of fruit infestation. This could be attributed to the fact that both products act as attractants to luring fruit flies and kill them when they feed on the GF-120 food bait sprayed on foliage and those that enter the Cocoa Butter Cream baited traps which may have died upon contact or inhalation of the DDVP killing agent placed in the traps.

Fruit yield was greater in the Cocoa Butter Cream treated plots at Faraba and all the product treated plots produced greater yields than the control. At Site 3, however, dimethoate treated plots produced the greatest yield. Generally, one can argue that the treated plots benefited from the protection of products applied and this translated into yield. Thus the treatments applied benefited the plants by giving them some protection.

5. CONCLUSION

This study has shown that even though *Bactrocera dorsalis, Dacus vertebratus* and *Zeugodacus curcubitae* occur in the study areas, only *Dacus vertebratus* infest watermelon fruits in the West Coast Region of The Gambia. Both Success Appat (GF-120) and Cocoa Butter Cream reduced watermelon fruit infestation, generally providing comparable protection as Dimethoate to watermelon fruits against fruit flies. Therefore, both Success Appat (GF-120) and Cocoa Butter Cream could alternately be applied to Dimethoate insecticide to reduce both fruit's infestation and chemical applications in watermelon farming. Again, extension workers and farmers should be trained on management of fruit flies using the integrated options such as proper field sanitation and burying of infested watermelon fruits. Finally, further studies are required to know the residue levels in watermelon fruits after the application of these two products.

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