Impact of Insect Infestation on Plant Damage and Yield of Roselle [*Hibiscus sabdariffa* L.] in Benue State, Nigeria

ABSTRACT

Impact of insect infestation on growth and yield of Roselle (*Hibiscus sabdariffa* L.) was evaluated at the Teaching and Research Farm of University of Agriculture, Makurdi, in the 2016 cropping season. An early and late crop (as main plot), of the red (*H. sabdariffa sabdariffa*) and green (*H. sabdariffa altissima*) types (as subplot) were planted in Randomized Complete Block Design (RCBD) with split-split-plot arrangement. Four weekly application of 100 g a.i/ha of cypermethrin + 400 g a. i./ha of dimethoate constituted sub-subplot treatments. All treatments were replicated three times. Insects were visually counted in 1 m^2 area in two rows of each plot. The dominant insect pests included *Monolepta thomsoni, Nisotra sjostedti, Dysdercus volkeri and Oxycarenus hyalinipennis*. The early crop differed significantly (having 9 % wider stem girth, 2x more branches/stem, and 1.5x more leaf damage) from the late crop. The green Roselle had more pod (2.5x) and seed (1.1x) damage and gave from 1.3 – 1.5x lower calyx, pod and seed yield. Plant growth and productivity were significantly higher in sprayed than in the unsprayed plots. Plants sprayed at both vegetative and reproductive stages were the most productive having significantly more fresh leaf biomass (2.5-103.6x), calyx yield (2.6-2.8x), pod yield (2.2-7.4x), seed yield (3.1-11.0x) sequel to more vigorous growth and less pod damage (2.0-44.6x) and seed damage (1.8-8.6x). Cost-benefit analysis indicated that the red Roselle was more profitable than the green, the late crop was more profitable than the early, and protection at both vegetative and reproductive stages was more profitable than other spray regimes returning N440,291.25/ha, N755,291.5/ha, and N397,236.0/ha for leaf, calyx and seed valuation, respectively. Insecticidal protection of the crop has been shown to mitigate drop damage and return profit.

Keywords: Insect infestation, *Hibiscus sabdariffa*, Growth, Yield, Cypermethrin, Dimethoate

Introduction

Roselle (Hibiscus sabdariffa L) from the family Malvaceae is an important vegetable crop in tropical and sub-tropical regions of the world (5, 20). In Africa, the major producing countries of *H. sabdariffa* var. *sabdariffa* include Republic of Benin, Sudan, Cote D' Ivoire, Ghana, Niger, Burkina Faso, and Nigeria (17). The crop has many domestic and industrial uses (5). Locally, the dried red calyx is processed into a colorful cold beverage and the green calyces and bracts are also used to prepare soup/sauce. In many parts of the world, leaves and stalks are consumed as green vegetable/salad (12,17). In Nigeria, Roselle is intercropped with staple food (e.g. yam, maize, sorghum) or oilseed (e.g. Beniseed) crops, or planted along field margins preponderantly by women; they add value to the crop by developing products for the market (14). Different phenological stages of Roselle (seedling, flowering and fruiting stages) are attacked by various insect pests some of them causing economic losses (2,1). In the peasantry, polycultural system of crop production in Nigeria, the inclusion of two or more malvaceous crop is prevalent, thus encouraging cross infestation and damage by insects (3). The study aims to research on the impact of insect infestation on plant damage and yield, as there are very limited works.

Roselle is an economically very important ~~miracle~~ plant with various utilizations (Crane 1949). The leaves and calyx are used as vegetable in many countries of the tropics. There are three different color groups: green, red, dark red are available in the tropics (Purseglove 1977). The calyx of red and dark red types are used to extract juice for fresh drink after sweetened and the leaves of green types are used as vegetables (Babalola 2000). Roselle contains high amount of vitamin C and anthocyanins which makes it unique for nutritional characteristics. Nutritionists have reported that roselle calyces are high in Ca, K, Mg, Na, niacin, riboflavin and iron (Islam et al., 2016).

Worldwide business of roselle calyces is increasing day by day. The large importers of the world are Germany and the United States. Each year, the U.S. imports more than 5,000 metric tons of dried roselle calyces valued at $22 million for use in making herbal teas. Egyptian and Sudanese roselle are highly paid, 1200-1700 US$ per ton in United States and Germany as compared to the price of Chinese roselle (www.uses.plantnet-project.org). The quality of roselle of China and Thailand is low because of excessive precipitation during production ~~due to~~ so that its prices is only 4000 US$ per ton. Other than China and Thailand, currently 18 companies of Malaysia are also engaged in the production, processing and marketing of roselle products for the local market. The current annual export value of fresh calyces to be RM2.5 million in Malaysia. The domestic market consumes roselle calyces of around 500 tons per year, of which over 80% is used to process juice and drinks. in Malaysia, total market value of the roselle industry is to be RM10.0-15.0 million whereas about 65-80% of the value remains with the processor (Mohammad et al. 2002).

Materials and Methods

Experimental Site: The study was conducted during 2016 cropping season at the Teaching and Research Farm, Federal University of Agriculture, Makurdi, Benue State. Located in the southern guinea savanna zone of Nigeria. Makurdi lies between 7°44N and 8°35E with an altitude of 228m above sea level.

Seed Source: Two types of Roselle, the red calyx *H. sabdariffa* var. *sabdariffa* and the green calyx *H. sabdariffa* var. *altissima* were purchased locally

Layout: Randomized Complete Block Design (RCBD)with split-split-plot arrangement of treatments replicated three times. Treatments were early- (mid-June) and late-sown (mid-August) crop as the main plot treatments, the varieties *H. sabdariffa* var. *altissima* (Green calyx) and *H. sabdariffa* var. *sabdariffa* (Red calyx) served as the sub-plots treatment and application of 1000ml a.i/ha formulation of cypermethrin + dimethoate at: vegetative growth stage, reproductive growth stage, vegetative and reproductive growth stages, and an untreated control as the sub-sub plot treatments. Each experimental plot measured 5 m x 5m (the Roselle types were planted on a ridge at a spacing of 1m X 1m between and within rows, respectively.); adjacent plots were separated by 1 m alley while space between adjacent replications was 2 m.

Application of Treatment: At vegetative stage, spraying commenced at 3 weeks after planting (WAP) and was repeated four times at weekly intervals while at the reproductive phase spraying commenced at 50 % flowering and was similarly repeated four times.

Data Collection

Plant damage data: At 8 WAP and at harvest, plants in 1 m x 1 m section of rows 2 and 4 of each plot were visually examined, number of insect perforated leaves, flower, pod and calyces per plant ~~per plant~~ quantified. Leaf damage was assessed using leaf damage score where:0=no leaf damage,1=25%leaf damaged, 2=26-50%damaged leaf, 3=70% damaged leaves, 4=100% damaged leaves, 5=Total defoliation

After pod harvest, drying and shelling was done in order to determine seed yield. One hundred seeds were then selected at random/plot, soaked in water and the floated seeds (indicative of damage) were counted. Percentage seed damage was then computed using this formula:

$$\textbf{Percentage seed damage} = \frac{\textbf{Number of floated seeds}}{\textbf{Total number of seeds}} x\ 100$$

Yield Parameters

At harvest, 1 m x 1 m section of rows 2 and 4 were randomly selected and all the leaves of the plants within harvested. Yellow leaves as well as entangled weeds were removed and the fresh edible/marketable and unmarketable leaves were then weighed per plot. The calyx and pods from the three inner rows of each plot were harvested and weighed. The calyx was then sundried and weighed. The pods on plants in the three inner rows were picked, counted and weighed. The number of pods/plant then was then computed. Twenty pods were selected at random, shelled, and the seeds gathered and

weighed. The number of seeds/pod was computed. All pods from the three inner rows of each plot were shelled and the seeds weighed to determine the seed weight/plot. A random of 100 seeds was taken and weighed.

Cost: benefit analysis: Cost benefit analysis was calculated based on the method of Shabozoi et al., 2011 (19). Total crop protection expenses were calculated by multiplying per spray cost with the total number of sprays throughout the crop growing period, benefit per hectare was determined by subtracting plant protection expenses from the total income generated per hectare which was determined based the present market price of the leaves, seeds and calyces of Roselle. Due to fluctuation in prices throughout the year, price per kilogram of Roselle leaves, calyces and seeds were fixed at 500, 1100 and ₦1150 per kg respectively for the analysis. Cost benefit ratio of each spray regimes for the different planting dates was worked out by subtracting income of control from net income of spray regimes and the product was divided by total cost of crop protection for each treatment.

Data Analysis -All data were subjected to analysis of variance (ANOVA) using Genstat Software Package and significant means ($P < 0.05$) were separated using Fisher's least significant difference (FLSD) at 5% level of probability.

RESULTS

Effect of cropping season, Roselle variety and spray regimes on plant damage parameters

Numbers of insect- perforated leaves per plant were 1.4 – 1.6 higher ($P<0.05$) in the early- than in the late-sown crop at both 8WAP and at harvest. There were no significant differences ($P>0.05$) in leaf damage score index, numbers of insect-perforated calyces (8WAP and AH) and flowers/plant (8WAP), number of insect-perforated pods/plant and percentage seed damage at harvest. However, the number of insect- perforated pods/plant at harvest was significantly 1.9x higher ($P<0.05$) in the late than the early crop. At 8WAP, insect damage in terms of the numbers of insect-perforated leaves, calyces, flowers per plant, as well as ~~in terms of~~ leaf damage score, was significantly ($P<0.05$) more on the green- than on the red-type Roselle. At harvest both Roselle types differed significantly ($P<0.05$) only in the number of insect-perforated pods/plant and percentage seed damage with higher damage occurring on the green-type, but varietal differences in numbers of insect- perforated leaves, calyces and pods/plant as well as in the leaf score index were not significant ($P>0.05$).The untreated plots had significantly greater insect damage except in the plots sprayed at the vegetative stage only where leaf perforations at 8 WAP and at harvest were significantly higher and where fruit boring at 8 WAP was statistically comparable. At 8WAP, calyx perforation was reduced by 61.0 % in the plots sprayed at vegetative stage and by 99.1 % in the plots sprayed at both vegetative and reproductive stages, at harvest, the values were 62.5 % and 96.5 %, respectively. Number of insect perforated pods/plant significantly decreased at both 8WAP and at harvest by 24 and 50.8% in plots sprayed at the vegetative stage, 98 and 99 % reduction were recorded in vegetative and reproductive sprayed plots. Significant reduction over the untreated plot was also observed in the number of insect perforated flowers in the vegetative and vegetative and reproductive sprayed plots amount to 63.87 and 98.95 % respectively. (Table 1)

Effect of cropping season, Roselle variety and spray regime some yield parameters

Planting Roselle early resulted in significantly ($P<0.05$) 1.7x marketable leaf yield than planting the crop late but fresh calyx yield was 1.10 x higher in the late than in the early crop. However, no significant differences ($P>0.05$) in weight of unmarketable leaves, pod, seed, 100-seed weight, percentage dry matter and number of pods/plant (8WAP and AH). In seven out of the 10 yield parameters quantified, the red-type Roselle gave significantly better performance than the green-type (Table 2).Increase in productivity ranged from 5.8 % in 100-seed weight to 34. 8 % in fresh pod yield. Differences in weight of unmarketable leaves and the numbers of pods/plant at both 8WAP and at harvest were not significant. All spray regimes resulted in significant increases in yield and component of yield above the level in unsprayed plots (Table 2).The higher the frequency of spraying, the higher the increase in yield. In all yield parameters, the plots sprayed at both vegetative and reproductive stages differed significantly from the plots sprayed at vegetative or reproductive stage alone.

Benefit-cost analysis of production of marketable fresh leaves, dry calyx, and seeds of Roselle

Across cropping season and variety, profit from the sale of fresh leaves, dry calyx and seeds was 4.0-10.8 fold greater in the plots sprayed at the vegetative and reproductive stages than in other treatment plots. Of the three plant produce, dry calyx production in the early crop was the most profitable (=N=862,030:00), followed by seed production in the late crop (=N=776,854:00), and leaf production of the early crop (=N=674,450:00).The red-calyx Roselle gave >2-fold the profit margin of the green-calyx Roselle (=N=2,094,535:00)and overall profit of the late crop exceeded that of the early crop (=N=4,541,047) by =N1,368,590:00. For seed production, spraying the early crop at the vegetative stage was not profitable.

Table 1: Main effects of cropping season, Roselle variety and spray regimes on plant damage parameters

Variable	Number of insect perforated leaves/plant*		Leaf damage score		Number of insect perforated calyces/plant		Number of insect perforated flowers/ plant	Number of insect perforated pods/plant		% Seed damag e
	8WAP	AH	8WAP	AH	8WAP	AH	8WAP	8WAP	AH	AH
Cropping season										
D1	50.73	55.50	2.79	3.08	0.64	1.56	6.05	0.98	1.91	40.21
D2	35.04	35.30	2.17	2.54	0.91	1.64	11.42	1.86	3.16	43.58
$FLSD_{0.05}$	10.91*	5.66*	ns	ns	ns	ns	ns	0.80	ns	ns
Roselle variety										
V1	52.67	46.80	2.63	2.83	1.03	2.15	10.90	2.07	3.63	43.29
V2	33.10	44.00	2.30	2.79	0.52	1.05	6.56	0.77	1.44	40.50
$FSLD_{0.05}$	4.14*	ns	0.16*	ns	1.08*	ns	1.70*	0.71*	0.82*	0.70*
Spray regimes										
S1	64.15	59.20	1.92	3.58	0.83	1.62	8.99	2.43	3.95	47.00
S2	48.55	34.50	3.50	1.92	0.14	0.32	0.81	0.18	0.48	27.50
S3	3.97	26.50	1.17	1.25	0.02	0.15	0.26	0.05	0.18	9.67
S4	54.88	41.40	4.30	4.50	2.13	4.32	24.88	3.03	8.03	83.43
$FLSD_{0.05}$	8.95*	11.66*	0.33*	0.30*	0.33*	0.54*	3.66*	0.63*	0.85*	3.10*
Interaction										
DXV	ns	*	ns	ns	*	ns	*	ns	ns	*
DXS	*	*	*	*	ns	ns	*	*	*	ns
VXS	*	ns	*	ns	*	*	*	*	*	*
DXVXS	*	*	*	ns	ns	ns	ns	*	ns	*

D1=Early sown Roselle, D2= Late sown Roselle, V1=Green type, V2=Red type,S1=Vegetative stage only, S2=Reproductive stage only, S3=Vegetative and Reproductive stage, S4= Untreated Control, WAP=Weeks after planting, AH=At harvest

Table 2: Main effects of cropping season, Roselle variety and spray regimes on plant on some yield parameters

Variable	Leaf yield (Kg/ha)		Calyx yield (Kg/ha)		Number of pods/plant		Pod yield (Kg/ha)		Seed yield (kg/ha)	100-Seed Weight (g)
	Marketable	Unmarketable	Fresh	Dry	8WAP	AH	Fresh	Dry		
Cropping Season										
D1	1827.32	1014.14	2340.89	250.75	9.58	83.20	2103.10	253.96	221.77	2.32
D2	1105.25	645.15	2587.54	288.35	13.49	73.40	2286.09	309.18	302.17	2.33
$FLSD_{0.05}$	139.83*	ns	89.47*	ns	ns	ns	ns	ns	ns	ns
Roselle Variety										
V1	1256.02	764.36	1973.81	220.51	9.58	64.10	1732.78	230.88	211.44	2.26
V2	1676.55	894.93	2954.62	318.58	13.50	92.50	2656.41	332.25	304.15	2.40
$FSLD_{0.05}$	376.83*	ns	415.91*	46.88*	ns	ns	563.93*	70.95*	56.49*	0.04*

Spray Regimes										
S1	425.69	735.77	1727.22	202.83	7.12	51.50	1569.22	222.98	150.74	1.93
S2	1532.36	500.43	2067.66	212.24	12.72	73.40	1877.49	198.26	202.10	2.58
S3	3867.73	152.02	5387.78	589.26	22.73	165.80	4731.27	634.16	633.65	3.16
S4	37.35	540.37	674.20	73.85	3.60	22.50	600.40	70.87	57.36	1.64
$FLSD_{0.05}$	350.84*	308.13*	618.62*	74.51*	1.10*	17.8*	581.93*	90.10*	67.97*	0.09*
Interaction										
DXV	*	ns	ns	ns	ns	ns	ns	ns	ns	ns
DXS	*	*	*	*	*	*	*	*	*	ns
VXS	*	ns	Ns	ns	*	ns	*	*	ns	ns
DXVXS	*	ns	*	*	*	ns	*	ns	ns	ns

D1=Early sown Roselle, D2= Late sown Roselle, V1=Green type, V2=Red type,S1=Vegetative stage only, S2=Reproductive stage only, S3=Vegetative and Reproductive stage, S4= Untreated Control, WAP=Weeks after planting, AH=At harvest

Table 3: Benefit-cost analysis of production of marketable Roselle fresh leaves at Makurdi in the 2016 cropping season

Cropping Season	Crop Variety	Crop Stage Protected	Cost of Protection (=N=/ha)[3]	Benefit from Protection (=N=/ha)[4]	Benefit : Cost ratio
Early	HSS[1]	Vegetative	15200.00	50650.00	1.86
		Reproductive	15200.00	323850.00	19.83
		Vegetative + Reproductive	30400.00	674450.00	21.95
		Unsprayed control	0.00	37560.00	
	HSA[2]	Vegetative	15200.00	40033.33	1.22

		Reproductive	15200.00	293435.00	15.97
		Vegetative + Reproductive	30400.00	578550.00	18.82
		Unsprayed control	0.00	36700.00	
Late	HSS[1]	Vegetative	15200.00	29675.00	2.95
		Reproductive	15200.00	36035.00	3.37
		Vegetative + Reproductive	30400.00	383280.00	4.98
		Unsprayed control	0.00	0.00	
	HSA[2]	Vegetative	15200.00	12955.00	1.85
		Reproductive	15200.00	61115.00	2.07
		Vegetative + Reproductive	30400.00	124885.00	3.42
		Unsprayed control	0.00	0.00	

1HSS= Hibiscus sabdariffa var. sabdariffa
2HSA= Hibiscus sabdariffa var. altisimma
3Summed over the cost of insecticide, equipment and labour for application.
4Difference between income from sale of plant produce and cost of protection. Income was based on the market price of =N=500:00 /kg of fresh leaves

Table 4: Benefit-cost analysis of dry Roselle calyx at Makurdi in the 2016 cropping season

Cropping Season	Crop Variety	Crop Stage Protected	Cost of Protection (=N=/ha)[3]	Benefit from Protection (=N=/ha)[4]	Benefit : Cost ratio
Early	HSS[1]	Vegetative	15200.00	81017.00	2.34
		Reproductive	15200.00	331080.00	18.80
		Vegetative + Reproductive	30400.00	862030.00	27.36
		Unsprayed control	0.00	60577.00	
	HSA[2]	Vegetative	15200.00	67388.00	3.25
		Reproductive	15200.00	250956.00	15.33
		Vegetative + Reproductive	30400.00	728787.00	23.88
		Unsprayed control	0.00	33154.00	
Late	HSS[1]	Vegetative	15200.00	359097.00	14.35
		Reproductive	15200.00	105976.00	7.97
		Vegetative + Reproductive	30400.00	847224.00	18.90
		Unsprayed control	0.00	156200.00	
	HSA[2]	Vegetative	15200.00	247139.00	13.55
		Reproductive	15200.00	229066.00	-8.55
		Vegetative + Reproductive	30400.00	583125.00	16.20
		Unsprayed control	0.00	56320.00	

1HSS= Hibiscus sabdariffa var. sabdariffa
2HSA= Hibiscus sabdariffa var. altisimma
3Summed over the cost of insecticide, equipment and labour for application.
4Difference between income from sale of plant produce and cost of protection. Income was based on the market price =N=1,100:00/kg of dry calyx.

Table 5: Benefit-cost analysis of production of seeds of Roselle at Makurdi in the 2016 cropping season

Cropping Season	Crop Variety	Crop Stage Protected	Cost of Protection (=N=/ha)[3]	Benefit from Protection (=N=/ha)[4]	Benefit : Cost ratio
Early	HSS[1]	Vegetative	15200.00	-9565.00	0.01
		Reproductive	15200.00	14263.00	1.94
		Vegetative + Reproductive	30400.00	55861.50	2.84
		Unsprayed control	0.00	5462.50	
	HSA[2]	Vegetative	15200.00	-11370.50	0.09
		Reproductive	15200.00	7627.50	1.34
		Vegetative + Reproductive	30400.00	16842.00	1.47
		Unsprayed control	0.00	2495.50	
Late	HSS[1]	Vegetative	15200.00	330605.00	14.65
		Reproductive	15200.00	229140.50	16.08
		Vegetative + Reproductive	30400.00	776854.00	26.55

	Unsprayed control	0.00	123050.00	
HSA[2]	Vegetative	15200.00	287894.00	17.00
	Reproductive	15200.00	145995.50	-12.15
	Vegetative + Reproductive	30400.00	739387.00	17.28
	Unsprayed control	0.00	44620.00	

1HSS= Hibiscus sabdariffa var. sabdariffa
2HSA= Hibiscus sabdariffa var. altisimma
3Summed over the cost of insecticide, equipment and labour for application.
4Difference between income from sale of plant produce and cost of protection. Income was based on the market price of N=1,150:00/kg of seed

DISCUSSION

The number of insect perforated leaves was more in the early crop than the late crop. This can be attributed to higher number of leaf beetles being more abundant in the early than the late sown crop. However, greater number of pods were found to be perforated in the late sown crop compared to early sown Roselle could be due to the presence of more pod burrowing insects in the late than in the early sown crop. (14) reported okra having more perforated leaves in the early sown crop than the late sown crop this he stated might be due to lower populations of flea beetles in the late sown crop (26). In a study conducted separately by (11) and (8) they pointed out that planting date can an important tool when planning farm operations so that crops can avoid possible injury by emerging during period of low insect activities (27). (10) pointed out that biotic or abiotic stress can affect the growth, performance and yield of plants in both agricultural and natural system.

The green and red Roselle types showed differential reactions to infestation and damage by the insect pests. Green Roselle types recorded more damage leaves, calyx, pod, flower and seed than the red type, that is to say the green Roselle type is preferred by insect species more than the red type. It has been reported by Mohammed et al.(14) that some okra varieties differ in their response to insect infestation and damage. Ottai et al. (16) reported more infestation by spiny bollworm *E. insulana* on White than the Sudani and Masri varieties. Phytophagous insects have been reported to discriminate among various host plants, this might be as a result of changes in leaf hardness or as a result of chemical changes by phago-stimulants or the presence of secondary metabolites.(6). Morphological features may produce physical stimuli or bar insect activities (15). Hanelt (9) also pointed out that insect feeding activity is diminished in many crops because of morphological characteristics which may include pubescence, tissue characteristics and gummy exudates. The red type posses a number of insect and was able to yield more than the green type this might suggests tolerance of red variety insect infestation, as it was able to produce substantially calyx and leaves. The red Roselle type was noticed to possess spike like structures on pods, this might have served as a deterrent to the insect pests. Hanelt (9) attributed tolerance in some crops to changes in photosynthetic partitioning which led to high yield because of slight damage of photosynthetic tissues.

Spray plots recorded highest growth parameters, yield parameters and lowest damage parameters. This is in line with the findings of Mohammed et al. (14) who reported that sprayed okra varieties recorded more number of leaves, total dry matter, lesser number of damage leaves than the unsprayed plots. Somaila & Oaya (18) also reported that spraying cypermethrin + Dimeothate on 2 okra varieties led to significantly taller plants, more branches and leaves. Alao et al. (7) reported that Deltamethrin treated Roselle plants recorded higher calyx yield than the untreated control. The findings of this study is also in line with that which was reported by Aetiba & Osekre (4). They pointed out that Okra treated with Oxymatrine-based insecticides recorded lower damage parameters tan the untreated control in both early and late sown okra in Kumasi Ghana. Insecticidal protection of the crop during the vegetative +reproductive stages has been shown to mitigate drop damage and return profit for the two Roselle types.

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