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RELATIONSHIP BETWEEN CHEMICALS IN SOME MALVACEAE CROPS AND HOST- PREFERENCE BY *PODAGRICA SJOSTEDTI* JACOBY (COLEOPTERA: CHRYSOMELIDAE)

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ABSTRACT

Crops in the Family Malvaceae are attacked by similar pests at different stages of their development. One of such insect pests is *Podagrica sjostedti* Jac., a flea beetle, which is oligophagus in nature. Information on variations of its infestation level within Family Malvacaea and the influence of plant chemicals on these variations are scanty. This information is necessary for making appropriate decisions on non-chemical components of integrated pest management (IPM). Therefore, this study was carried out in the early season 2010, and was repeated within the same season. Its objectives were to determine the flea beetle preference among five (5) Malvacaeae crops and the chemical basis for the preference. A randomised complete block design (RCBD) was adopted with four replicates; the Malvacaeae crops trialled - okra, kenaf, red roselle, jute mallow and cotton represented the five (5) treatments. The five crops were established from seeds; from 3 weeks after planting, data were collected on the population of *P. sjostedti* and number of flea beetle-induced leaf holes, leaf area damaged and number of damaged leaves per plant. Significantly higher population of *P. sjostedti* was found on okra (7.90) compared to kenaf, red roselle and jute mallow; cotton however, had the lowest population of this insect. The leaf area damaged was significantly higher ($P < 0.05$) on okra (0.34) than on other crops, while the least was observed on cotton. The leaf contents of the primary and secondary metabolites varied significantly among the 5 Malvaceae crops. There was a significant positive correlation between the following plant chemicals - phytate, terpenes, flavonoids, tannin and crude fat on one hand and insect population, and leaf damage on the other. The relationship between plant chemicals - crude protein, dry matter, alkaloids, steroids, phosphorus and iron - and insect population (and leaf damage) was negative. Okra plant was the most preferred crop to the flea beetles, while cotton was the least preferred among the crops trialled in the Family Malvaceae; the phagostimulants responsible appeared to be phytate, terpenes, flavonoids, tannin and crude fat.

Keywords: *Podagrica sjostedti*, population density, damage, Malvaceae, plant chemical constituents, phagostimulants.

INTRODUCTION

The acceptance or rejection of plants by phytophagous insects depends on their behavioural response to plant features which may be physical or chemical (Bernays and Chapman, 1994). Differences in concentration of nutrients in plants influences host selection. However, the narrow ranges of phytophagous insects most commonly depend on the presence or absence of a variety of secondary metabolites in plants, so that plant chemotaxonomy is probably an important factor in understanding host ranges.

Family Malvaceae consists of over 200 genera flowering plants with close to 2300 well-known species . They are rarely small trees, with a worldwide distribution. The stems are often fibrous and the plants usually have stellate indumentums, leaves are alternate, simple usually palmately veined; stipules are present. Members of these groups are fibre crops which include okra (*Abelmoschus esculentus* (L.) Moench), kenaf (*Hibiscus cannabinus* L.), red roselle (*Hibiscus sabdariffa* L.), jute mallow (*Corchorus olitorius* L.) and cotton (*Gossypium* spp.). Their uses range from domestic consumption to animal feed ingredients and industrial raw materials (Burkill, 1997).

In Nigeria, *P. uniforma* and *P. sjostedti* are the common flea beetles species found infesting okra fields and other members of Family Malvaceae {Lana and Taylor, 1976; Vanlommel *et al.*, 1996; Integrated Pest Management Collaborative Research Support Program (IPM CRSP), 2001}. *P. sjostedti* is dominant in the early season while *P. uniforma* is more abundant in the late season (Odebiyi, 1980). Four stages are recorded during the life history; egg, larval, pupa and adult stages. The egg stage takes 7-13 days to hatch; larvae live in soil and feed on the epidermis tissues of the plant root. The pupal stage is spent in the soil. There are three or more generations per year (Oke and Odebiyi, 2008).

According to Odebiyi (1980), flea beetles infestation account for about 90% of the insect population found on okra. The larvae of the beetle attack the roots, eating off rootlets and make entry holes that allow contamination by some fungi and bacteria (Mohammed, 2000; IPM CRSP, 2001). The adults perforate the leaves (buckshot) and also feed on the capsule (IPM CRSP, 2001). On small plants, this "buckshot" damage can result in plant death (Mohammed, 2000). Moreover, flea beetles are important vectors of okra mosaic virus (OMV), a tymovirus accounting for about 18 - 26% yield loss annually (Atiri, 1984; Lana and Taylor, 1976; Lana 1976).

Among the subsistence farmers who practise mixed cropping in Nigeria, at least a member of Malvaceae can be found on their field during the cropping season. This practice encourages cross-infestation of pests of Malvaceae. Information on host preferences is invaluable in planning non-chemical control strategies such as trap cropping, crop rotation, etc., integrated pest management, host-plant resistance and in the understanding of nutritional requisites of insects. The objectives of this study were to determine the varietal preference in Family Malvaceae by *P. sjostedti* and to verify the relationship between plant metabolites and flea beetle density.

MATERIALS AND METHODS

The study was carried out two times in the early season, 2010, at the Teaching and Research Farm, University of Agriculture, Abeokuta, (UNAAB) Nigeria (7^o 15'N, 3^o 25'E, 159 m above sea level). The treatments were five (5) different Malvaceae crops viz: okra (LD 88 variety), kenaf (IFEKEN 400), jute mallow (*Corchorus olitorus*), red roselle and cotton (SAMCOT 11). The experiment was laid out in a Randomized Complete Block Design with 4 replicates. Plot sizes were 5 m by 5.4 m with 3 m wide border margin between plots.

Okra seeds were tested for viability by soaking them in water for 24 hours; non-viable seeds floated and were discarded. Three (3) seeds of okra were sown per hole at 50 cm x 50 cm and 2-3 cm deep; for jute, seeds were steeped in boiled simmering water for 10 seconds to break their dormancy; they were thereafter air-dried at room temperature and later mixed with dry soil in order to plant by drilling at 50 cm x 15 cm. Four kenaf seeds were sown at 2-3 cm depth at 75 cm x 30 cm and four (4) seeds of roselle were sown at 2-3 cm depth at 75 cm x 50 cm. For cotton, three seeds were sown at 90 cm x 30 cm. At three weeks after planting, all the crops planted were later thinned to 2 plants per stand. No insecticides were applied. Weeding was done at 15, 30 and 42 days after planting (DAP).

Data were collected on population density of *P. sjostedti*, leaf area damage, functional leaf area, average leaf area (cm^2) and damaged leaf per plant (%) on ten (10) randomly selected plants in a plot. The observation on the density of *P. sjostedti* spp. started 3 weeks after planting (WAP). The beetles were counted visually on a weekly basis on 10 randomly selected plants per plot early in the morning between 6:00 am and 7:00 am (local time) when they were less active and their density was high. Damaged leaf areas were calculated using graph sheet method. Ten leaves were randomly selected from each of the 10 plant species per plot. The number of feeding holes made by flea beetles characterised by round holes on each plant species were counted and functional leaf area was also determined. To remove the ambiguity of the differences in the leaf sizes of the trialled crops with respect to amount of damage, damage was based on number of holes per cm^2 of the leaves.

Proximate analysis of the leaves to determine the primary and secondary metabolites contents of each plant species as well as lignin contents was carried out. Data collected were subjected to analysis of variance (ANOVA) and significant means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of probability.

RESULTS

Data collected from the two experiments were similar and were therefore, pooled before analyses. The results showed that the population of *P. sjostedti* varied significantly ($P < 0.05$) on okra, kenaf, roselle, jute mallow and cotton (Table 1). Significant higher population of *P. sjostedti* was found on okra relative to other test crops while the least was observed on cotton. Similarly, leaf area damage, damaged leaves per plant and average number of holes per attacked leaves were significantly higher on okra than on other test crops, although no significant differences existed in these parameters among other test crops, except cotton that recorded significantly lower values for these parameters.(0.03).

There were large inconsistent variations in the contents of the primary and secondary metabolites found in the crops trialled (Table 2). Protein contents were significantly higher in jute mallow and significantly lower in okra compared to other crops. Similarly, higher moisture contents were recorded on okra, cotton, kenaf and roselle, and significantly lower on jute mallow.

Correlation analyses revealed that there was a significant and negative relationship between the following plant chemical constituents - such as crude protein, dry matter, alkaloids, steroids, phosphorus and iron on the one hand and insect population and leaf damage on the other (Table 3). The relationship between the plant chemical constituents - terpenes, phytate, ash, tannin, phenol and flavonoids – and insect population and leaf damage were positive and significant.

Table1: Population density of *Podagrica sjostedti* and leaf damage of Malvaceae crops

Crop	Mean population of Podagrica sjostedti /plant	Average leaf area (cm2)	Damaged leaves per plant (%)	Average number of holes per attacked leaf	Leaf area damage per cm2
Okra	7.90a	47.70b	34.15a	12.01a	0.34a
Kenaf	5.11b	30.22c	13.50b	3.48b	0.13b
Roselle	4.63c	22.15d	14.75b	3.54b	0.15b
Jute mallow	5.18b	21.90d	14.85b	3.09b	0.14b
Cotton	1.57d	52.97a	2.43c	1.08c	0.03c
Mean	4.87	34.98	15.93	4.64	0.15
C.V.	30.2	3.50	46.6	15.3	4.70

Means followed by the same alphabets in each column are not significantly different from one another at $P < 0.05$.

Table 2: Proximate analyses of different species of Malvaceae crops

Parameters determined	Jute mallow	Kenaf	Okra	Roselle	Cotton
Crude protein (%)	5.48a	3.27d	2.10e	3.40c	3.70b
Crude fibre (%)	1.57d	1.74b	1.06e	1.62c	1.84a
Crude fat (%)	0.24bc	0.21c	0.20c	0.26ab	0.28a
Ash (%)	0.42d	1.24a	0.37e	1.14b	1.04c
Moisture content (%)	82.20e	86.70c	91.40a	85.60d	86.74b
Dry matter (%)	17.40a	13.30c	8.60e	14.40b	13.26d
Lignin (%)	1.16d	2.14a	1.10e	1.24c	1.36b
Tannin (g/100g)	0.011c	0.134a	0.015c	0.130a	0.124b
Phenol (g/100g)	0.006b	0.120d	0.005d	0.024c	0.076b
Saponin (%)	0.130b	0.134c	0.140d	0.126a	0.132b
Alkaloids (%)	2.86d	1.71b	1.11a	1.75b	1.93c
Steroids (g/100g)	0.017b	0.112c	0.014a	0.012a	0.016b
Flavonoids (g/100g)	0.100b	0.017a	0.113b	0.018a	0.210c
Terpenes (g/100g)	0.034b	0.074c	0.013a	0.022b	0.146d
Phytate (g/100g)	0.124a	0.132b	0.124a	0.137b	0.151a
Oxalate (g/100g)	0.116b	0.117b	0.012a	0.141c	0.136c
Calcium (g/100g)	257.50c	234.10b	70.40a	214.60b	261.40c
Phosphorus (mg/100g)	127.50c	96.70b	47.60a	93.40b	82.66b
Iron	7.80c	4.94b	1.03a	4.80b	4.38b

Means followed by the same alphabets in each row are not significantly different from one another at $P < 0.05$.

Table 3: Correlation coefficients of the relationship between plant chemical constituents and leaf damage and *Podagrica sjostedti* density

Parameters determined	Leaf damaged	Insect density
Crude protein (%)	-0.36	-0.52
Crude fibre (%)	0.35	0.37
Crude fat (%)	0.50	0.42
Ash (%)	0.42	0.62
Moisture content (%)	0.36	0.43
Dry matter (%)	-0.36	-0.43
Lignin (%)	0.09	0.24
Tannin (g/100g)	0.52	0.70
Phenol (g/100g)	0.45	0.55
Saponin (%)	0.14	0.08
Alkaloids (%)	-0.36	-0.52
Steroids (g/100g)	-0.08	-0.06
Flavonoids (g/100g)	0.66	0.39
Terpenes (g/100g)	0.82	0.72
Phytate (g/100g)	0.87	0.86
Oxalate (g/100g)	0.16	0.19
Calcium (g/100g)	0.11	0.05
Phosphorus (mg/100g)	-0.46	-0.51
Iron	-0.40	-0.47

DISCUSSION

It could be deduced from the results that cotton was the least preferred for feeding by *P. sjostedti* and okra, the most preferred; the other crops – kenaf, roselle and jute mallow showed varying levels of preference to this beetle. The variation in the preference of these crops by the flea beetle as observed may be due to either morphological (in terms of leaf structure and composition) or chemical (primary and secondary metabolites). This is because phytophagous insects are known to discriminate among hosts as a result of changes in leaf hardness or as a result of chemical changes brought about by phagostimulants and other secondary metabolites (Akoroda, 1985).

Since *P. sjostedti* population and leaf damage were negatively correlated with the contents of alkaloids, crude protein, dry matter, steroids, phosphorus and iron, it implies that the lower the contents of these constituents in the trialled crop species, the higher the flea beetle population, and the higher the damage. These plant chemicals therefore, appear to be somewhat deterrent in nature. The lack of relationship between lignin content (or phenols which are precursors of lignin) and insect population (and damage) suggest that the flea beetle preference in the Family Malvaceae is not due to the toughness of the leaves. However, the positive correlation of phytate, terpenes, flavonoids, tannin and crude fat with insect population and leaf damage implies that these constituents were nutritionally beneficial to *P. sjostedti* and could likely be connected in some way to increase in flea beetle feeding.

This finding becomes interesting because paradoxically, the major chemical repellents recorded in plants are tannins, terpenes and various alkanoids (Hill, 2008). Tannins are mostly found in horsetails, ferns, gymnosperms, and some angiosperms, and they are quite antibiotic to many pathogens. They are essentially defence chemicals which make plants less appetizing for the herbivores (Landolt, 1997). Alkaloids are mostly found in angiosperms and are thought to be of more recent origin. It is thought that tannins were developed initially in the process of evolution as a deterrent to grazing replies, and the alkaloids similarly evolved as a protective mechanism in angiosperm to repel grazing mammals. However, insects are able to use the plant defence chemical as a feeding attractant, and this has turned out to be extraordinarily common, i.e. the supposedly deterrent chemical becoming the insect's phagostimulant, initiating and maintaining feeding behaviour. Example is the defence chemical, tannin, which is a phagostimulant to the gypsy moth on oak trees (Willmer *et al*., 2005), and tannic acid which is a stimulant to *Anacridium melanorhodon* and *Lymantria dispar* which are both caterpillars (Bernays and Chapman, 1994).

Similarly, the flavonoid glycoside rutin occurs in many different plant families and stimulates feeding in some polyphagous species such as the larva of *Helicoverpa zea* and the grasshopper, *Schistocerca americana* (Bernays *et al*, 1991). Luteolin-7-glucoside stimulates feeding in the beetle, *Chrysomela vigintipunctata*, linamarin which is a cyanogenic glycoside stimulates *Epilachna varivestis* (beetle), and linamarin (flavonoid glycoside) stimulates *Anthonomus grandis* (beetle) and *Bombyx mori* (caterpillar) (Bernays and Chapman, 1994). Also, some terpenes are taxon-specific and phagostimulatory for some insects; examples are monoterpenoid, catalpol in *Catalpa* and plantains which stimulates *Ceratomia catalpae* and *Euphydryas chalcedona* which are both caterpillars; gossypol (sesquiterpene) in cotton stimulates *Anthonomus grandis* (beetle) (Sperling and Michel, 1991).

More study is necessary to pin-point the exact phagostimulant among the chemical group implicated in this study; the mechanism of the operation of the stimulant must also be determined using the insect sensilla receptors or single-cell recording method. However, the effect of the phagostimulants and feeding deterrents on the flea beetles could be fully investigated in basic breeding works, and may be manipulated in order to obtain a resistant variety to the flea beetles. This approach may be a promising one in the management of *Podagrica* species. In the meantime, okra may be further investigated as a trap crop for the flea beetles. Planting of okra must also be carefully manipulated in a crop rotation system in order to break the infestation cycle of the flea beetles.

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