Combining Diamond Burbark, *Triumfetta rhomboidea* (Malvaceae) with Garlic Extract in Push-Pull Management of *Spoladea recurvalis* (Lepidoptera: Crambidae) on *Amaranthus hybridus* in Nigeria

Borisade, O. A., Ekiti State University Nigeria, Faculty of Agriculture, Department of Crop Science  
[omotoso.borisade@eksu.edu.ng](mailto:omotoso.borisade@eksu.edu.ng)

Ayotunde-Ojo, M.O., Ekiti State University Nigeria, Faculty of Agriculture, Department of Forestry and Wildlife Management, [moyo.ayotunde-ojo@eksu.edu.ng](mailto:moyo.ayotunde-ojo@eksu.edu.ng)

Uwaidem, Y.I., Ekiti State University Nigeria, Faculty of Agriculture, Department of Crop Science, [yuwaidem@gmail.com](mailto:yuwaidem@gmail.com)

Abstract—Entomological pests severely undermine amaranth production in Nigeria where the Beet webworm moth, *Spoladea recurvalis* and *Psara basalis* were responsible for the most significant damage. Surveys were conducted at two different infested areas (Area-A and Area-B) in the Southwest to identify wild hosts that relay the pest populations into new crop cycles. The spiny amaranth, (*Amaranthus spinosus*) was found in Area-A while the diamond burbark (*Triumfetta rhomboidea*) and *A. spinosus* were in Area-B. For the purpose of pest identification, larvae samples were collected from the plants habouring mixed lepidopteran larvae and reared to adult in the laboratory. *S. recurvalis* was the predominant pest in the two surveyed areas. The ratio of *P. basalis* to *S. recurvalis* populations on the spiny amaranth in Area-A was 20% to 80%. In Area-B, 90% of the larvae samples from *A. spinosus* developed into adult *S. recurvalis* while 10% was *P. basalis*. Thereafter, the diamond burbark was applied as a border crop around amaranth plots and water extract of garlic was sprayed on the amaranth. The garlic spray and the diamond burbark served as the ‘push’ and the ‘pull’ components of a stimulo-diversionary management system respectively. The control consisted of amaranth plots sprayed with garlic extract only (without border crop). The experiment was conducted in amaranth production field infested naturally by *S. recurvalis*. Significantly (P<0.05) lower damage (7.2%) occurred where amaranth was bordered with *T. rhomboidea* and sprayed with garlic extract, while 64.6% damage was recorded where garlic extract spray alone was used (control). The paper reported the potentials of combining *T. rhomboidea* with garlic extract to mitigate pest attack against leaf amaranth in Southwestern Nigeria. The method presents environment friendly pest management, capable of reducing reliance on the use of chemical pest management approaches.

Key words: *Amaranthus spinosus*, diamond burbark, push-pull, *Spoladea recurvalis*
INTRODUCTION

Amaranthus hybridus (Amaranthaceae) is an important vegetable crop cultivated for its edible leaves in Nigeria. The leaves contain substantial amounts of vitamins, proteins and minerals (1) and it is relatively cheaper than other vegetable crops with equivalent nutritional qualities. It is one of the most widely cultivated leafy vegetable in Southwestern Nigeria (2, 3).

The diamond burbark, T. rhomboidea (Malvaceae) is widespread in Africa. It is a fiber tropical plant which its dehiscent seeds disperse by explosive mechanism. The barst fiber of the plant have been found useful in making ropes and nets while the leaves and the stem are important in African traditional medicine. Despite the various uses of the plant, it is uncultivated and regarded as a weed, growing on lawns, roadsides and among cultivated crops in Nigeria.

The larvae of the spinach moth (Spoladea recurvalis) (Lepidoptera: Crambidae) is responsible for most of the economic damage to leaf amaranth in the Southwestern Nigeria (4). It feeds extensively on amaranth leaves and cause ‘skeletonization’, contamination of leaves with excrements and webbings, rendering the produce unmarketable. S. recurvalis is found all year round, posing a serious threat wherever leaf amaranth is cultivated in the wet and dry seasons, and it is the main target of control programs. Adults visit amaranth fields at night to lay eggs on lower leaves surface and the eggs hatch within 3-5 days into the larvae, which is the pestiferous life stage (5).

Within the study area, levels of damage that are inconvenient for farmer’s interest and economics occur at low and high pest densities. However, the economic thresholds for the insect and the magnitude of yield loss due to S. recurvalis damage have not studied. The economic crops which are alternative hosts to S. recurvalis are aubergine, bean and curcurbits- especially melon and water melon (5), but there is no report on the wild host plants that relay the pest into the next production cycle or cropping season.

In Nigeria, control of lepidopteran pests of leaf amaranth has been a challenge because the adults do not feed on amaranth and insecticide sprays that are often scheduled at morning hours fail to target the adults that are nocturnal. The half-life of an inorganic chemical is often more than the time from seeding to harvest of leaf amaranth, leaving significant amount of residues in the fresh vegetable. However, chemical insecticides are increasingly employed in the management of amaranth pests, because the available alternative approaches- intercropping systems and light trapping, that are eco-friendly had proved ineffective, particularly when populations were rapidly increasing.

The trends of chemical use is getting worse because there are no clear government policies and enforcements on pesticide use and food safety. Supportive policies on Integrated Pest Management (IPM), where the use of pesticides would be the last resort are lacking. The absence of monitoring and control programmes on pesticide use, coupled with handling of pesticides by untrained personnel has often led to over-use or misuse. Currently, more than two hundred brands of different pesticides are been imported into Nigeria, among which are persistent and highly toxic organochlorides. Adeyeye and Osibanjo (6) reported that aldrin, dieldrin, dichlorodiphenyltrichloroethane (DDT) and other pesticides which were de-registered because their persistence in the environment and extremely high bio-toxicity are among those employed in the management of vegetable pests. Application of higher insecticide concentrations are likely in the future, based on the present trends of use (6, 7,8) and the likelihood of pests becoming
resistant to some of these insecticides. Despite the intensive use of these pesticides in some agro-ecological areas in Nigeria, many farmers were forced to abandon their farmlands in response to frequent pest attacks.

We conducted a pest survey targeted at identification of wild hosts to *S. recurvalis* by examination plants that exhibit characteristic symptoms of Lepidopteran larvae attack. The aim of the study was to identify wild hosts on which the pest populations subsist in the absence of leaf amaranth, and exploit them in devising an eco-friendly management option to reduce reliance on the use of chemicals. The paper evaluated the efficacy of garlic extract combined with *T. rhomboidea*, planted as a border crop, to mitigate pest attack against leaf amaranth.

II. MATERIALS AND METHODS

A. Study Area and Survey of Wild Hosts

The survey was carried out in Ado Ekiti, Ekiti State in the South Western Nigeria (7.6667° N and 5.2500° E) on some of the abandoned fallow land (which is referred to as Area A henceforth). The land was divided into four approximately equal sub-plots and scouting for skeletonized plants within the area was conducted on each of the plots by randomly visiting infested plants. The intensity of skeletonization, presence of webbings and excrements on the different host plants were visually assessed. Samples of plants showing signs of insect feeding which were similar to activities of Lepidopteran larvae were collected and brought to the laboratory for identification in the Department of Plant Science, Ekiti State University, Nigeria. Five different positions of each of the identified host plants were marked using red-painted poles, 1.5 m in length. The first survey was conducted in October at the onset of the dry season and the second was done in February at the beginning of the rainy season. Based on the information supplied by the local farmers, the timing of the survey coincided with the periods that *S. recurvalis* infestations were usually most severe on leaf amaranth in the agro-ecological area. Similar search for wild host plants was conducted in amaranth producing regions of Ekiti (5°10' N and 6°51' E) (which is referred to as Area B henceforth) within the state, where organic leaf amaranth mono-cropping system have been successful (without economically important levels of pest attacks).

B. Collection and Rearing of Larvae

The marked plants were visited at night between 8:00 -10:00 pm when the larvae were actively feeding. Samples of larvae on different host plants were collected randomly into glass jar with perforated lid and brought into the laboratory. Between ten and twenty larvae samples collected from similar host plants at different spots in Areas A and B were mixed and reared on potted *A. hybridus* inside a net cage (Figure 1) for 1-2 weeks or until emergence of adults. The adult insects were used for identification with reference to (5). Where there were more than one species that emerged in the cage as adults, the relative number of each species was expressed as a percentage of the total number of adults in the cage. This was used to assess the ratio of the species in the mixed infestations that were present on the different host plants.
FIGURE I. LEPIDOPTERAN LARVAE REARING CAGE CONTAINING POTTED *A. hybridus* AS FOOD.

Only the samples of larvae collected in October were used for the assessment of the percentage of species in the mixed infestations (Equation I).

\[
\text{Relative percentage of species on host plant} = \frac{\text{Number of each species}}{\text{Total number of adults in cage}} \times 100 \quad (I)
\]
C. Trap-Cropping Using Wild Host Plant and Application of Garlic Spray

In the abandoned land area, eighteen locations which were 30-50 meters apart were selected and cleared for cultivation of *A. hybridus*. Twelve of the locations were randomly assigned to preparation of beds measuring 2.5 m x 3.5 m, which was surrounded by 1.2 m perimeter space and 0.5 m wide trap plant, *T. rhomboidea* (Figure 2). The space between the bed and the perimeter was sprayed with a systemic pre-emergence herbicide, Oxygal® (Oxylfluoren 240 g/l) to prevent weeds before harvesting of the leaf amaranth. Between 10-15 g of *T. rhomboidea* seeds were sown around the perimeter of each bed and allowed ten days before *A. hybridus* was planted. This was done to ensure that *T. rhomboidea* foliage established ahead of the leaf amaranth. Beds measuring 2.5 m x 3.5 m without the trap plant were assigned to the six remaining locations to serve as control and the perimeters were equally sprayed with Oxygal®. *Amaranthus hybridus* seeds were mixed with sand in ratio 1:10 (seed: sand) and broadcasted on each bed at the rate of 4.0 kg seeds ha⁻¹ (3.5 g bed⁻¹).

After ten days, water extract of garlic (*Allium sativum*) prepared by mixing 50 g garlic powder with one liter of distilled water at 60 °C in hot water bath for one hour was filtered, allowed to cool to ambient temperature and sprayed using a Knapsack sprayer on the amaranths in the eighteen plots at the rate of 500 ml extract plot⁻¹. Air drifting of the garlic spray into the perimeter plant was prevented. The first trial amaranth production was conducted in October, 2015 and repeated during the same period in 2016.

![FIGURE II. LAYOUT OF *A. HYBRIDUS* PLOT AND *T. rhomboidea* PERIMETER TRAP CROP](image-url)
D. **Sampling and Assessment of Damage**

At three weeks, six of the amaranth-*T. rhomboidea* plots were selected randomly and the perimeter plant (*T. rhomboidea*) was removed. Six other beds remained with the trap plant and damage assessment was done immediately. Damage assessment was repeated at two other periods: when the amaranth was four and six days overdue for harvest. The samplings were done using a quadrat (Area = 30 cm$^2$) thrown randomly at six different positions on each plot. The total number of stands of amaranth in the quadrat as well as the damaged were counted. The criteria used for determination of damage was based on the local consumer’s acceptable quality standards for leaf amaranth and the reasons for rejection in the market. These were summarized: (a) amaranth stands showing 2-3 skeletonized leaves (b) the presence of insect fecal contaminations (c) signs of webbings and folded leaves. Recorded values of the number of damaged amaranth stands in the quadrats were averaged for each bed and expressed as a percentage of total plant in the quadrat area using the equation:

$$\text{Percentage damage} = \frac{\text{Number of damaged amaranth stands}}{\text{Total number in the quadrat area}} \times 100$$  \hspace{1cm} (II)

Thereafter, larvae samples were collected randomly from *T. rhomboidea* at the borders and reared on potted amaranth inside the net cage until emergence of adults. This was done to confirm the identity of the pests.

III. **STATISTICAL ANALYSIS**

A two-way between groups analysis of variance (ANOVA) was conducted to explore the effect of *T. rhomboidea* boarder plant + garlic spray and garlic spray alone on vegetative damage by pest. Where significant differences were found, means were separated using Tukey’s Honestly Significant Difference (P=0.05). Data analysis was done using the IBM-SPSS 21 Statistical Software and graphs were plotted with MS Excel 2013.

IV. **RESULTS**

A. **Host Plant Profiles of the Surveyed Areas**

The identified wild host plants to the two major pests (*S. recurvalis* and *P. basalis*) of leaf amaranth in Area-A were the spiny amaranth (*A. spinosus*) and wild cowpea (*Vigna* spp). Left-overs of cultivated amaranth also harboured significant pest numbers (Table 1). The ratios of *P. basalis* to *S. recurvalis* populations on *S. spinosus* and left-over amaranth in the abandoned farmland, Area-A were 20% to 80% and 10% to 90% respectively. Small populations of *Spoladea recurvalis* only was found on the wild cowpea, and their activities were mild, based on visual assessments of the levels of vegetative damage.

In Area B, the wild hosts consisted of two plants; the spiny amaranth and the diamond burbak (*Triumfetta rhomboidea*), while left-overs of *A. hybridus* from previous production cycle and uncultivated fluted gourd (*Telfairia occidentalis*) were found harbouring various Lepidopteran larvae. The fluted gourd is an important crop planted for its leaves and seeds which are used in traditional soups in Nigeria. However, the few stands growing in the survey area were not cultivated. Ninety percent of the larvae samples collected from *A. spinosus* developed into adult *S. recurvalis* while 10% was *P. basalis*. All the larvae samples collected from *T. rhomboidea* and *A. hybridus* left-overs
TABLE 1. HOST PROFILES AND POPULATION RATIOS OF *Spoladea recurvalis* AND *Psara basalis* ON THEIR HOST PLANTS IN THE TWO SURVEYED AREAS.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Common name</th>
<th>Botanical name</th>
<th>Host status</th>
<th>Area A</th>
<th>Area B</th>
<th>Area A</th>
<th>Area B</th>
<th>Visual observation of pest activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Spiny amaranth</td>
<td><em>A. spinosus</em></td>
<td>Wild host/weed</td>
<td>Present</td>
<td>Present</td>
<td>80%</td>
<td>90%</td>
<td>Severe</td>
</tr>
<tr>
<td>2</td>
<td>Left-over amaranth</td>
<td><em>A. hybridus</em></td>
<td>Crop left-over</td>
<td>Present</td>
<td>Present</td>
<td>90%</td>
<td>100%</td>
<td>Severe</td>
</tr>
<tr>
<td>3</td>
<td>Fluted gourd</td>
<td><em>Telfairia occidentalis</em></td>
<td>Crop/uncultivated</td>
<td>Absent</td>
<td>Present</td>
<td>**</td>
<td>100%</td>
<td>Mild</td>
</tr>
<tr>
<td>4</td>
<td>Diamond burbank</td>
<td><em>T. rhomboidea</em></td>
<td>Wild host</td>
<td>Absent</td>
<td>Present</td>
<td>**</td>
<td>100%</td>
<td>Severe</td>
</tr>
<tr>
<td>5</td>
<td>Wild cowpea</td>
<td><em>Vigna spp.</em></td>
<td>Wild host/weed</td>
<td>Present</td>
<td>Absent</td>
<td>100%</td>
<td>**</td>
<td>Mild</td>
</tr>
</tbody>
</table>
were \textit{S. recurvalis} when they developed into adults. The larvae samples from \textit{T. occidentalis} were identified as the spiny bollworm (\textit{Earias biplaga}) (Lepidopteran: Noctuidae) at adult stage. \textit{E. biplaga} is a polyphagous Lepidopteran pest that is not classified as leaf amaranth pest. The intersection of host plants in the two surveyed areas were \textit{A. spinosus} and \textit{A. hybridus} left-overs while \textit{T. occidentalis} and \textit{T. rhomboidea} were peculiar to Area B.

\subsection*{B. Leaf Amaranth Vegetative Damage}

There was a statistically significant main effect of \textit{T. rhomboidea} border plant on vegetative damage of amaranth by pests \textit{F}(2, 533) = 62.5, \textit{P}=0.0001 (Table 2). Predominantly, \textit{Spoladea recurvalis} and few \textit{P. basalis} in a mixed infestation were responsible for the damage to the leaf amaranth, based on the characteristic appearance of the attacked amaranth leaves (Figure 3) and the sighted adults (Figure 4). At the time the leaf amaranth was due for harvest in the first trial, the mean percentage damage on \textit{T. rhomboidea} bordered amaranth (TBA) was 7.26\% while a significantly higher damage (64.6\%) was recorded in the control (Figure 5). When the TBA was four days overdue for harvest, there was a significantly higher increase in the mean percentage damage, 22.5\%. However, a further delay of harvest for additional two days showed no significant increase in damage (25.2\%). The level of damage in the control was significantly the highest from the time that the amaranth was due for harvest and six days after.

There was no statistically significant difference in the outcome of the results of the two trials, \textit{F}(1, 533) = 0.997, \textit{P} = 0.318 The damage on TBA when harvest was due and after four and six days delay of harvesting were 9.3\%, 15.3\% and 22.5\% respectively in the second trial. In the plots where the border plants were removed when the leaf amaranth was due for harvesting, vegetative damage increased significantly thereafter (Figure 6). During the first trial, when harvesting was delayed for two days after the removal of the border plant, vegetative damage to amaranth increased to 32.5\% from the initial of 7.26\%. Similarly, the damage of 40\% which was.
FIGURE III. AMARANTH LEAVES SHOWING CHARACTERISTIC DAMAGE PATTERNS OF *S. recurvalis* AND *P. basalis* ATTACK
FIGURE IV. IMAGE SHOWING (A) ADULT Spoladea recurvalis MOTH AND (B) THE CHARACTERISTIC WHITE MARKINGS ON THE WING.
FIGURE V. EFFECT OF COMBINING GARLIC SPRAY WITH *T. RHOMBOIDEA* TRAP CROP AND USE OF GARLIC SPRAY ALONE ON PERCENTAGE DAMAGE TO LEAF AMARANTH BY *S. recurvalis* and *P. basalis* MIXED INFESTATION (A) IN THE FIRST TRIAL AND (B) SECOND TRIAL.
FIGURE VI. EFFECT OF REMOVAL OF *T. rhomboidea* BORDER PLANT ON RATE OF DAMAGE TO LEAF AMARANTH BY *S. recurvatus* and *P. basalis* MIXED INFESTATION.
recorded when harvesting was four days overdue increased to 52% after additional two days delay. In the second trial, 9.3% damage was recorded when the leaf amaranth was due for harvest but increased to 31.5%, 40% and 61% when harvesting was delayed for 2, 4 and 6 days respectively.

V. DISCUSSION

This study showed that entomological pests, particularly the Lepidopterans and the Othopterans are the most important constraint to production of leaf amaranth in the study area. Other studies in the Southwestern Nigeria showed that Lepidopterans and Orthopterans are the major pests of leaf amaranth (4, 9). *Triumfetta rhomboidea* as a wild host of the amaranth pest, *S. recurvalis* and its application in push-pull pest management in combination with plant extract is being reported for the first time.

Management of field pests using habitat management and stimulo-divisionary approaches, which involve combinations of ‘push’ and ‘pull’ components, could offer a sustainable and eco-friendly alternative to the use of chemical insecticides, eliminating risks of killing non-target insects and environmental concerns (10). Success with this technique may depend considerably on correctly identifying the right components which could be combined under different pest scenarios and cropping systems. In the current report, amaranth pests were attracted to the alternative host and their populations were reduced below economic injury level on the main crop. There is no data to compare the results of the Push-Pull system involving the use of alternative food source to divert pests away from amaranth. However, Push-Pull strategies have been reported in the management of tomato pests (11) and stem borers (12, 13) in different parts of Africa. In other related studies, *Desmodeum uncinatum* and Elephant grass have been combined as the ‘Push’ and the ‘Pull’ components respectively, exploiting the chemical ecology of the plants (14).

The intensive survey of weed and non-weed hosts to *S. recurvalis* and *P.basalis* was conducted in the leaf amaranth producing agro-ecological areas in the early dry season period and at the onset of the rain season, to understand host divergence in relation to cropping periods. The study showed that *S. recurvalis* and *P.basalis* subsisted on wild amaranth and *A. spinosus* and *A. hybridus* stands that were left unharvested in the previous production cycle. This is consistent with the earlier report by James et al. (2010) (5) on studies of hosts to major lepidopteran pests of leaf amaranth in West Africa. However, *Triumfetta rhomboidea* was identified for the first time as an alternative and a wild host plant to *S. recurvalis* in Southwestern Nigeria.

The host intersection in areas A and B were *A. spinosus* and *A. hybridus* left-overs while a non-amaranthaceae alternative host, *T. rhomboidea* was recorded in Area B only. It can be suggested that the absence of alternative wild hosts diversity (non-amaranthaceae) capable of sustaining the populations of *S. recurvalis* and ecologically harmful farm practices; non- destruction of crop left-overs at closed season periods and chemical control-only, were responsible for pest concentrations on the cultivated *A. hybridus* in area A. We concluded that the presence or the absence of diversity of wild hosts can either be detrimental or advantageous, depending on the kind of pest that is responsible for crop damage in a particular area and its food preference behaviours. Where polyphagous herbivours show a greater preference for the wild host rather than the cultivated crop, significant numbers of the pest populations may be lured away from the main crop. While alternative hosts serve as another source of food, they exert other influences, which may include conservation or attraction of natural enemies (15, 16, 17).
Insect pests are known to locate their hosts using either olfactory cues or a combination of olfactory or visual cues (18). Host plants produce karmones to which specific pests are attracted (19). The major factor to consider before application of trap plants and repellants that act as host acceptance modifying stimulus include the chemical ecology of the main crop. Thus, cultural practices that are capable of interfering with insect-host plant relations in terms of visual and olfactory cues are likely to be useful ‘push’ components of a push-pull pest management strategy. In the current study, the strong odour of garlic extract sprayed on the amaranth probably acted as a repellent or triggered host preference responses that favoured *T. rhomboidea* the preferred food. Garlic have been shown to contain the compound, allicin (20), that showed repellency against storage pests (21,22). Garlic also contains volatile organic compounds which may overshadow the effect of green leaf volatiles (GLV); host searching karmones, to which most phytophagous insects are sensitive and reduced the capacity or the accuracy of the lepidopterans to locate their target. Garlic is known to disrupt insect mating pheromone communication system (23).

The alternative host plant, *T. rhomboidea* was planted a week ahead of the main crop to ensure that it established first and the pests become used to the alternative crop before the main crop becomes available. It may be interesting to evaluate the effect of sequence of availability of alternative food sources on pest establishment and host preference behaviours, which we were unable to examine in the current study. Such data may be clearly necessary in the design of main crop-alternative hosts stimulo-diversionary systems in a push-pull strategy for the management of important agricultural pests.

A significant damage occurred where garlic extracts were applied without the perimeter wild host, *T. rhomboidea*. It appeared that the pests soon overcome the effect of the garlic odour in the absence of an alternative source of food. There are also possibilities that the garlic had relatively short deterrent effects under interacting abiotic factors- temperature, solar radiation and rainfall. There is no information on persistence of garlic odour or sprays against field pests. However, responses of different insect pests and their abilities to overcome the effects of botanical extracts-mediated stimuli are expected to vary under different abiotic interactions, although this has not been established in any study.

The survey showed that *S. recurvalis* was responsible for most damage although significant numbers of *P. basalis* were present. The results of a similar survey in another part of Western Nigeria showed that *Hymenia recurvalis* (new name=Spoladea recurvalis) was the predominant and the economic pest of *Amaranthus cruentus*. It was also reported that diversity and relative abundance of insect pests associated with *Amaranthus* species varied with season, probably due to rivalry for food (24) and seasonality of alternative hosts.

**VI. CONCLUSION**

We demonstrated the use of wild alternative host as a perimeter trap crop, representing the pull component and combined this with botanical extract, which was the push component in the management *Spoladea recurvalis* and *Psara basalis* that are the major lepidopteran pests of *A. hybridus* for the first time in Nigeria. The pest populations were successfully kept below levels that were inconvenient for the farmers who deserted their farmlands when pest problems could no longer be managed by the use of chemical insecticides, considering food safety concerns. The
factorial design with twelve replicates showed that success was positively correlated with the pull stimulus and there was a significant difference in the results of the push and the push-pull systems. *T. rhomboidea* occur naturally in most parts of West African regions and there are potentials it can be employed in management of *S. recurvalis*. 
REFERENCES


