

1
2 **Insect pest profile of leaf amaranth (*Amaranthus hybridus***
3 **L) and prevention herbivory using vegetable oil-based**
4 **extracts of *Alium sativum* L, *Xylopia aethiopica* Dunal and**
5 ***Eucalyptus globolus* L**

6 **ABSTRACT**

7 Pest profile of *Amaranthus hybridus* was recorded in a single organic agro-
8 ecosystem in Southwestern Nigeria between November-December in 2016 and
9 January-February 2017, during the dry season. Activities of different pests were
10 monitored to identify those responsible for the most significant damage. Vegetable
11 oil-based extracts of *Alium sativum*, *Xylopia aethiopica* and *Eucalyptus globolus*
12 were prepared and applied on *A. hybridus* as protectants against herbivory by
13 phytophagous insects and damage to foliage was were assessed. Thereafter, the
14 extracts were rated based on the mean percentage damage (MPD) recorded in
15 different plots in relation to the treatments. A total of nine pests were recorded from
16 three insect Orders namely, Orthoptera (62.5%), Coleoptera (12.5%) and
17 Lepidoptera (25%) and they were grouped into Major, Minor or Occassional pests
18 based on their activities. Two lepidopterans, *Spoladea recurvalis* and *Psara basalıs*
19 (Family: Crambidae) were responsible for the most significant damage. All the
20 extracts reduced damage with statistically significantly difference ($P < 0.05$) compared
21 with the control. The MPD in *X. aethiopica*-, *A. sativum*- and *E. globolus*-treated plots
22 and the control plots were 10.9%, 8%, 14% and 31.2% respectively, when the
23 amaranth was due for harvest in the first trial. The MPD to the amaranth in the

24 treated plots during the second trial was between 13.6% and 16.3% when harvest
25 was due while the MPD in the control was 54.9%. The performances of *E. globolus*
26 and *X. aethiopica* were comparable and they were relatively more effective in
27 protecting *A. hybridus* against phytophagous pest attacks.

28 **Keywords:** *Amaranthus hybridus*, Herbivory, Phytophagous insects, Damage, plant extracts

29 INTRODUCTION

30 *Amaranthus hybridus* is widely cultivated in Nigeria for its edible leaf which contains
31 significant amounts of dietary proteins, vitamins and minerals (Akubugwo et al.,
32 2007). It is well adaptable to the climatic conditions in different agro-ecological zones
33 in Nigeria. In the South West, which is the major production hub, dry season
34 amaranth cultivations are restricted to wetland areas or locations with proximity to
35 water for irrigation. It is a rapid source of income for subsistent and poor-resource
36 farmers because of its relatively short production cycle (14-21 days), simple method
37 of cultivation and high market demands. During the dry season, supply of leaf
38 amaranth often falls short of the demand, the price becomes relatively high
39 (Emokare et al., 2007) and there are periods when amaranth is completely
40 unavailable in the market.

41 Insect pests seriously undermine vegetable production in Nigeria, particularly when
42 they are cultivated for their foliage. Pest density is often high and attacks are severe
43 in the dry season due to relative scarcity of alternative hosts. Amaranth is attacked
44 by a myriad of insect pests in a succession that depends on how long the crop is left
45 in the field (cultivated for leaf or seed) before harvesting. The insect pests that are
46 responsible for the most economic damage to leaf amaranth in the Southwest belong
47 to Lepidoptera and Orthoptera Orders (Joseph et al., 2016; Borisade and Uwaidem,

48 2017a). When leaf amaranth foliage has fully developed, sometimes losses of up to
49 100% can be incurred within one week in pest endemic areas if appropriate pest
50 control action is not initiated.

51 The major Lepidoptera pests of amaranth, *Spoladea recurvalis* and *Psara basalis* lay
52 their eggs on the abaxial parts of early foliage at night, about one week after the
53 appearance of the first foliage, thereby concealing infestation or potential
54 development of pests on the amaranth (James et al., 2010). The eggs hatch into the
55 larvae in about seven to fourteen days, which feed voraciously on the foliage. Major
56 damage often occur between 15-21 days after sowing, although earlier attacks are
57 possible. Apart from the feeding activities that 'skeletonize' the leaves, bulk of the
58 produce is often contaminated with frass and excrements that further reduce quality.
59 *Psara basalis* especially produce characteristic webbings on the leaves, which
60 makes the crop completely unmarketable (Borisade and Uwaidem, 2017a).
61 Grasshoppers and Katydid and many other phytophagous insects that move into
62 the field are also responsible for damage.

63 The use of chemical insecticides in vegetable pest management and the unsafe
64 levels of pesticide residues that are left in fresh vegetables are of a serious concern
65 (Akan, et al., 2013). Increasingly and from time to time, chemical pesticides are
66 being reviewed and unregistered for use in the management of vegetable pests,
67 considering their toxicity to non-targets and levels of persistence in the environment.
68 Chemical pesticides may be especially unsafe for pest management in the Nigerian
69 leaf amaranth production system, where the production cycle of 14-21 days is far
70 less than the half-life of the active ingredients in majority of the pesticides in use.
71 Chemical pesticides of the Organochloride groups and those containing DDT, which
72 are forbidden in the management of pests in food crops are found in agrochemical

73 retail outlets in Nigeria, and they are being used in the management of vegetable
74 pests by subsistent farmers. Thus, there is the need to reduce dependence on
75 inorganic chemicals in the control of leaf amaranth pests by seeking alternative
76 environment-friendly options.

77 Plants contain organic chemical constituents that protect them against herbivory and
78 disease pathogens and many of these constituents have great potentials for pest
79 management. Garlic (*Alium sativum*), *Xylopi aethiopica* and *Eucalyptus globolus*
80 are widely distributed tropical plants containing extractable bioactive compounds,
81 which have been employed in pest control in different studies (*Ebadollahi, et al.,*
82 2017; *Moshi and Matoju, 2017*). *Alium sativum* contains alicin, which is repellent or
83 toxic to eggs, developmental stages, and adults of many economic pests (*Huang et*
84 *al., 2017*). *Xylopi aethiopica* and *E. globolus* are also known to contain essential
85 oils reported to show repellency, ovitoxicity and aduIticidal effects against insect
86 pests (*Kouninki et. al., 2007*). However, many of the promising evaluations on the
87 use of extracts of these plants for crop protection were limited to store pests in *invitro*
88 bioassays. Efficacy of botanical extracts in field pest management is expected to
89 vary under variable interacting abiotic environmental factors: temperature and
90 relative humidity, often encountered under field conditions. In the field, pests are not
91 confined by limited space, a factor which may become a challenge against plant
92 extracts that are relatively slow in action.

93 Thus, the aim of this study was to record occurrence of pests on *Amaranthus*
94 *hybridus* within a single organic agro-ecosystem in South-Western Nigeria and
95 evaluate the propensity of oil extracts of *A. sativum*, *X. aethiopica* and *E. globolus* to
96 prevent damage.

97 **MATERIALS AND METHODS**

98 **Description of experimental site**

99 The study was carried out at Ekiti State University Teaching and Research Farms,
100 Ado-Ekiti, Nigeria (7.6124° N and 5.2731° E), from November to December 2016
101 and repeated between January and February 2017 during the dry season under
102 irrigation system. The study area has an average temperature of 25 °C with wide
103 fluctuations between day and night. The wet season is usually from April –October,
104 with bimodal rainfall pattern which peaks in June and October, while the dry season
105 is from November to March. The study area has a history of severe attacks on dry
106 season amaranth.

107 **Land preparation and experimental design**

108 The land was cleared and plant debris were packed before the preparation of beds.
109 The size of each bed was two square meter and a space of 0.5 m was left between
110 the beds. The experiment was a Randomized Complete Block Design (RCBD) with
111 three replications. Thus, the field consisted of nine blocks with three beds each, for
112 the treatments and three additional blocks assigned to control. Three other separate
113 blocks were created for the assessment of pest profiles. About 4 kg of poultry
114 manure was spread on each bed and mixed with the top layer of the soil. Thereafter,
115 the beds were irrigated, at least once in two days for a period of ten days to facilitate
116 the decomposition of the poultry manure before sowing. Each block was about 10 m
117 apart to eliminate the influence of a treatment over the other.

118 **Calculation of seed rate**

119 Crop Density, CD (=number of seeds to be sown per square meter) was determined
120 by measuring the weight of seeds equivalent to an estimated value using the
121 proposed formula for standardizing the seed rate of amaranth, Uwaidem and

122 Borisade (2017b), here summarized.: $E (g) = \frac{W}{NS} \times \frac{R}{1}$, where E = Equivalent weight (g),
123 W =Weight of 1 g amaranth seed, NS = Counted number of amaranth seed g^{-1} , R =
124 Required number of plants per bed. One seed of the amaranth used in the current
125 study weighed 0.000441g. Thus, considering an approximate plant density of 500
126 stands m^{-2} , 0.22 g of the amaranth seeds were sown on each bed.

127 **Sowing and post-planting management**

128 Dry sand was passed through 0.5 mm mesh and 100 g of the fine sand was mixed
129 with the seed for even seed distribution during sowing. A plastic container with a tight
130 fitting lid (100 ml) was modified for sowing the seeds by creating pin-sized
131 perforations (~ 0.5 mm) on the lid. The sand-seed mixture was poured into the
132 plastic and used for broadcasting the seeds. The beds were watered as required
133 using a Watering Can during afternoon periods until the amaranth was due for
134 harvest.

135 **Preparation of vegetable oil-based extracts of plants**

136 Five hundred grams of fresh bulbs of *A. sativum* and dry fruits of *X. aethiopica* were
137 chopped manually using a knife and poured separately in one litre-glass jar with a
138 tight fitting lid. Five hundred ml of vegetable oil was poured into each jar to submerge
139 the contents and kept at $-4^{\circ}C$ for one hour. Thereafter, the contents of the jar: (*X.*
140 *aethiopica* fruits + vegetable oil) or (*A. sativum* bulbs + vegetable oil) were blended
141 to form an oily paste. Fresh *E. globulus* leaves (500 g) were harvested in the
142 morning and shredded using a knife. The sliced leaves were poured into one litre-
143 glass jar and 500 ml vegetable oil was poured to cover the leaves. The glass jars
144 were transferred into Microwave (Model LG i-wave, MS2021F). Microwaving was
145 done at the Medium-High Power in three 10 minute-sessions, followed by 25 minutes
146 power-off after each session. The oil was separated by vacuum filtration at $4^{\circ}C$ and

147 stored in air tight bottles at 4°C. These were used as the stock plant extract in
148 subsequent assays.

149 **Assessment of pest profile and nature of damage**

150 Visual survey of insect pests on the amaranth was commenced at six days after
151 sowing and this continued until maturity. Scheduled daily visits to the field was done
152 in the morning (6:00-9:00 am), afternoon (12:00 noon-3:00 pm) and evening (6:00
153 pm-8:00 pm), to scout for insect pests. Insect samples were collected and brought
154 into the Agricultural Entomology Laboratory of the Crop Protection Unit, Faculty of
155 Agricultural Sciences, Ekiti State University, Nigeria for identification. The nature of
156 damage and severity of the activities of the pests were visually assessed on the
157 plant. Camera shot of damage to foliage was processed into a JPEG picture
158 presented as a photographic data. The pests were classified into three groups:
159 Major, Minor and occasional pests, based on their occurrence, density and severity
160 of damage to the crop. **Application of extracts and assessment of damage**

161 The plant extracts were randomly assigned to different blocks and the blocks were
162 labelled. At ten days after sowing, 50 ml of the extract of each plant was mixed with
163 200 ml water. The resultant mixtures were emulsifiable without the addition of a
164 surfactant. They were sprayed on the amaranth in each block using a hand operated
165 Knapsack Sprayer (1 Liter capacity) until leaves were dripping. The control plots
166 were sprayed with a mixture containing 50 ml vegetable oil + 200 ml distilled water.
167 The spraying was repeated after five days and damage assessment was conducted
168 at 24 days after sowing, when the leaf amaranth had reached the acceptable
169 maturity standard for local market sales. Sampling to assess damage was done with
170 a quadrat (Area = 20 cm²) thrown randomly at five different positions on each bed
171 and the total number of stands of amaranth within the quadrat area as well as the

172 damaged were counted. The criteria used for damage assessment was based on the
173 local consumers acceptable quality standards for leaf amaranth and the reasons for
174 rejection (Borisade and Uwaidem, 2017a). These were summarized: (a) amaranth
175 stands showing 2-3 skeletonized leaves (b) the presence of insect faecal
176 contamination or frass (c) signs of webbings and folded leaves. The recorded
177 number of damaged amaranth stands within the quadrats were averaged and
178 multiplied by the total area of the block. Thereafter, the value was expressed as a
179 percentage of the total number of plants in a block:

180
$$\text{Percentage damage per block} = \frac{\text{Number of damaged amaranth stands}}{\text{Estimated total number of amaranth per block}} \times \frac{100}{1}$$

181 RESULTS

182 Pest profile of *Amaranthus hybridus*

183 The pest profile of leaf amaranth within the single organic agro-ecosystem is shown
184 in **Table 1**. Nine pests from three Orders: Orthoptera, Coleoptera and Lepidoptera
185 were recorded during the first and the second amaranth production cycles. Only the
186 adults of the majority of the Orthopterans, such as the Burrowing cricket
187 (*Velarifictorus micado*), Slant-faced grasshopper (*Orphulella speciosa*), Variegated
188 grasshopper (*Zonocerus variegatus*) and the Green-striped grasshopper
189 (*Chortophaga viridifasciata*) occurred on the amaranth. Their frequency of
190 occurrence was relatively low and they were few in number. Thus, they were
191 classified as occasional pests, causing non-economically important damage in the
192 current evaluation. The nymphs and adults of the Angle-winged katydid
193 (*Microcentrum rhombifolium*), occurred frequently on the amaranth and they were
194 found voraciously feeding on the leaves causing potentially economic damage. It
195 was therefore classified as a major pest. Actively flying adults of two types of moth,
196 *Psara basalis* and the beet webworm moth (*Spoladea recurvalis*) as well as their
197 larvae occurred at all the sampling periods. The adults of these lepidopterans
198 occurred most frequently in the evening while a few was found resting under the
199 leaves during the day. The larvae were voracious feeders and they were responsible
200 for the most significant damage to the leaves (**figure 1**).

201 Assessment of damage and performance rating of extracts.

202 **Table 2**. shows the mean percentage damage (MPD) to the leafs of *A. hybridus*
203 sprayed with emulsifiable oil extracts of *X. aethiopica*, *A. sativum* and *E. globolus* at
204 5, 10 and 15 days after application. There were significant variabilities ($P=0.014$) in

205 **Table 1. Pest profile of *Amaranthus hybridus* within a single organic system in Southwestern Nigeria**

206

Common name	Scientific name	Order	Family	Recorded life stage responsible for damage	Pest status (Based on occurrence, numbers & crop damage activities)
Angle-Wing Katydid	<i>Microcentrum rhombifolium</i>	Orthoptera	Tettigoniidae	Adult and Nymph	Potential/Major
Crickets	<i>Velarifictorus micado</i>	Orthoptera	Gryllidae	Adult	Occasional/Minor
green stripped grasshopper	<i>Chortophaga viridifasciata</i>	Orthoptera	Acrididae	Adult	Occasional/Minor
Slant-faced grasshopper	<i>Orphulella speciosa</i>	Orthoptera	Acrididae	Adult	Minor
Variiegated grasshopper	<i>Zonocerus variagatus</i>	Orthoptera	Pyrgomorphidae	Adult	Occasional/Minor
Darkling beetle	<i>Lagria villosa</i>	Coleoptera	Lagriidae	Adult	Occasional/Minor
Moth	<i>Psara basalis</i>	Lepidoptera	Crambidae	Larvae	Major
Beet web worm	<i>Spoladea recurvalis</i>	Lepidoptera	Crambidae	Larvae	Major

207

208 **Table 2. Mean percentage damage to *Amaranthus hybridus* treated with oil**
 209 **extracts of *X. aethiopica*, *A. sativum* and *E. globolus***

FIRST TRIAL				
Days after treatment	<i>X. aethiopica</i>	<i>A. sativum</i>	<i>E. globolus</i>	Control (Vegetable oil)
5	4.28 ^a	1.19 ^a	1.23 ^a	25.37 ^b
10	9.59 ^{a,b}	25.26 ^{a,c}	3.94 ^b	41.27 ^c
15	10.19 ^{a,b}	8.01 ^a	14.00 ^{a,b}	31.42 ^b
SECOND TRIAL				
Days after treatment	<i>X. aethiopica</i>	<i>A. sativum</i>	<i>E. globolus</i>	Control (Vegetable oil)
5	2.38 ^a	4.76 ^a	3.51 ^a	30.69 ^b
10	6.80 ^a	35.00 ^b	10.32 ^a	32.24 ^b
15	16.30 ^a	18.75 ^a	13.57 ^a	54.88 ^b

210

211 Values in the same row and sub-table not sharing the same superscript are significantly different at $p < .05$ in the two-sided test of equality
 212 for column means. Cells with no subscript are not included in the test. Tests assume equal variances. Tests are adjusted for all pairwise
 213 comparisons within a row of each innermost sub-table using the Bonferroni correction



214

215 **Figure 1. Characteristic damage caused by Lepidopteran pests of *Amaranth*,**
216 ***Psara basalis* and *Spoladea recurvalis***

217 the MPD in relation to the extracts as well as the sampling periods. The MPD in the
218 control was significantly the highest in the first and the second trials. At 5 days post-
219 treatment during the first field trial, the MPD recorded in the *X. aethiopica*-, *A.*
220 *sativum*- and *E. globolus*-treated plots were not significantly different, being 4.28%,
221 1.19% and 1.23% respectively, while the MPD in the control plot was 25.37%. The
222 effect of these extracts were also not significantly different in the second trial at five
223 days post treatment (MPD in treatment, 8.49-19.5%; MPD in control=30.69%). At 10
224 days and 15 days post-treatment, the MPD in the *X. aethiopica*-treated plots were
225 not significantly higher, 9.59 % and 10.19% respectively in the first trial. The lowest
226 MPD were recorded in the *X. aethiopica*- and *A. sativum*- treated plots at 15 days in
227 the first trial being, 10.19% and 8.01% respectively and without statistically
228 significant difference. However, significantly higher MPD were recorded in the control
229 at these sampling periods and the values were 31.42% and 54.88% respectively.

230 Based on the pooled values of MPD recorded at the three sampling periods in the
231 two successive trials, the extracts were grouped according to their overall
232 performance using Tukey's Honestly Significant Difference (HSD) (Table 3). The
233 performances of *E. globolus* and *X. aethiopica* were comparable and they were
234 relatively more effective in protecting *A. hybridus* against phytophagous pest attacks.

235

236 **Table 3. Ranking of oil extracts of *X. aethiopica*, *A. sativum* and *E. globolus***
 237 **based on the mean percentage damage recorded on treated *Amaranthus***
 238 ***hybridus*.**

Tukey HSD ^{a,b}		Subset		
Plant Extracts	N	1	2	3
<i>E. globolus</i>	18	7.7617		
<i>X. aethiopica</i>	18	8.2556		
<i>A. Sativum</i>	18		15.4956	
Control	18			35.9778
Sig.		.997	1.000	1.000

Means for groups in homogeneous subsets are displayed based on observed means. The error term is Mean Square (Error) = 52.881.

a. Uses Harmonic Mean Sample Size = 18.000.

b. Alpha = .05.

239

240 **DISCUSSION**

241 The study has described the pest profile of leaf amaranth within a single organic
 242 agro-ecosystem, where 63% of the recorded pests were Orthopterans, 25% were
 243 Lepidopterans belonging to the Family Crambidae and 13% Coleoptera. The range
 244 of pests being reported are among those described in earlier studies in other parts of
 245 Southwestern Nigeria (Ezeh *et al.*, 2015; Oke *et al.*, 2015) except the Darkling beetle
 246 which has not been widely associated with leaf amaranth. Leaf amaranth pests
 247 within a single organic agro-ecological region was evaluated in this study and it is
 248 expected that the pest profile of crops in agro-ecological regions that share
 249 resemblances in temperature, humidity, vegetation patterns and cropping systems
 250 would be similar.

251 Biodiversity of insects pests associated with indigenous leaf amaranth species in
 252 Nigeria is increasing (Oke *et al.*, 2015). It is therefore useful to update data on

253 profiles of major vegetable crops from time to time, in order to identify new pests
254 which are getting adapted to new crops. Such data would be clearly necessary in the
255 development of pro-active pest response systems to militate against an outbreak. In
256 many earlier studies, insects were recorded as pests on amaranth by virtue of their
257 occurrence, while the levels of damage caused by each pest was often ignored
258 (Banjo *et al.*, 2003; Oke *et al.*, 2015). The presence of an insect pest on a crop may
259 not adequately indicate its status and justify its classification as economically
260 important under a given cropping condition. The recorded pests in this report were
261 classified into Occassional, Minor, Potential and Major pests using characteristics of
262 damage on the crop (feeding patterns) to identify activities of individual pests or
263 groups and visual evaluation of the levels of damage to establish the severity of
264 attack. It is useful to identify the specific economically important pests that could be
265 potential targets of a pest control programme. However, the status of a given pest
266 may change under different cropping systems, climate and human related
267 environmental perturbations.

268 Incidentally, the insects classified as major pests in this study comprised those
269 breeding on the amaranth. The results suggested that economically important pests
270 of amaranth are essentially those that are capable of breeding on the crop or at a
271 proximity to the crop and capable of completing their life cycle or reaching their
272 pestiferous life-stage before the host plant is due for harvest, except where migrant
273 pests are probably involved. Attack on crops can be much severe when more than
274 one of the life-stages of the pest are responsible for damage, such as the Katydid or
275 when the habit of the pest inflict qualitative damage in addition to quantitative losses
276 caused by their direct feeding. For example, contamination of leaves with frass,
277 webbings and excrements was peculiar to *S. recurvalis* and *P. basalis*. Different

278 instar larvae and adults of the two Lepidopteran *P. basal*i and *S. recurvalis* were
279 present, indicating their breeding on the amaranth and they were responsible for the
280 most significant damage whereas, mainly the adults of the Orthopterans and the
281 Coleopteran were found on the amaranth. Similar reports on the pest status of *P.*
282 *basalis* and *S. recurvalis* showed they are serious pests of leaf amaranth in different
283 agro-ecological regions in Nigeria and other parts of West Africa (James et al.,
284 2010).

285 The oil extracts of the three plants significantly reduced vegetative damage to *A.*
286 *hybridus* compared to the control and the results have demonstrated their potentials
287 for use in the management of vegetable pests at the level of subsistent farming. The
288 method of extraction described is simple, easily transferable and could be adopted
289 by poor resource farmers. The procedure can also be applied to other plants with
290 volatile bioactive components. The three plant materials contain volatile bioactive
291 substances, which may potentially be lost depending on the method of extraction
292 used. Deep freezing of the plant materials before milling and reduction processes
293 was done to minimize adverse effect of temperature during milling on loss of heat-
294 labile, volatile constituents. Direct blending of the plant materials with vegetable oil
295 was also done to trap oil-soluble volatiles during the milling process.

296 The levels of damage recorded at five days post-application of the three extracts
297 were not significantly different statistically. However, between 5-10 days post-
298 treatment, the MPD increased significantly where *A. sativum* extract was applied.
299 Abiotic interactions (temperature, UV and relative humidity) (Kumar and Poehling,
300 2006) are capable of influencing persistence of organic pesticides rapidly, through
301 their effects on evaporation and chemical decomposition in the field, indirectly

302 affecting overall efficacy. This may be responsible for the increased damage
303 recorded during sampling at 10 days post-treatment.

304 Insect pests are known to locate their hosts through visual and olfactory cues (Bruce
305 et al., 2005) and plant extracts with strong odour may interfere with the capability of
306 pests to accurately locate their targets. However, when the effect of the odour of the
307 plant extracts subside, there are possibilities that more pests would successfully
308 locate their food source. It may also be possible that the extracts were toxic to some
309 of the pests or offered some antixenosis resistance to the plant- that probably
310 diminished over time. More studies are needed in the development of stable
311 formulations capable of yielding consistent results under a dynamic or marginal
312 abiotic influences in the field.

313 The extracted plants; *X. aethiopica*, *A. sativum* and *E. globolus* have been applied
314 into various uses in folk medicine, pharmacy as well as food components (Konning
315 et al., 2004; Tattelman, 2005). Although concentrations of these plant materials that
316 may be toxic to humans are yet to be established and the amounts detectable on
317 treated plants have not been evaluated, they are not expected to cause bio-toxicity
318 or environmental contamination problems when applied on edible vegetables. They
319 can be considered as relatively safe compared with inorganic pesticides.

320 **Conclusion**

321 This study compared the effect of the extracts at a single dose and the MPD to the
322 treated plants over time was used to assess efficacy. More studies are needed to
323 quantify the actual concentrations of bio-active constituents in the plant materials.
324 The effects of the extracts against each of the identified pests need to be studied
325 separately, to evaluate their modes of action, including repellency, toxicity to adults

326 and developmental stages and antixenosis effects. However, the current results are
327 useful primary information in the design of further *invitro* and field studies.

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