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Different trap plants could affect biological parameters of *Plutella xylostella* LINNAEUS, 1758 (Lepidoptera: Plutellidae)

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Abstract

Potential of trap crops are mainly measured by two properties, high attractivity for oviposition and low suitability for growth and development. In the present study, six biological parameters of diamondback moth, *Plutella xylostella* (LINNAEUS, 1758), including larval survival, larval developmental time, pupal survival, pupal developmental time, pupal weight and adult sex ratio were evaluated on five different cruciferous host plants, namely, *Brassica oleracea* var. *botrytis*, *Brassica pekinensis*, *Sinapis alba*, *Sinapis arvensis* and *Alyssum maritima* in laboratory experiments to determine their suitability for diamondback moth growth and development. Observed adult sex ratios had no significant deviation from the expected ratio of 1:1 and pupal survival did not show meaningful difference among host plants. The other four biological parameters had significant differences on host plants in such a way that the longest larval developmental time (9.9 days), the least larval survival (21.2%), the longest pupal developmental time (5.6 days) and the least pupal weight (2.6 mg) obtained on *A. maritima*. Based on results, *A. maritima* had low suitability for diamondback moth growth and development.

Key words: Biological parameters, host plant suitability, *Plutella xylostella*, trap crop.

Zusammenfassung

Die Wirksamkeit von Pflanzenfallen wird hauptsächlich an zwei Eigenschaften gemessen: hohe Attraktivität für die Eiablage und geringe Eignung für Wachstum und Entwicklung der Brut. In dieser Studie wurden sechs biologische Parameter der Kohlschabe, *Plutella xylostella* (LINNAEUS, 1758) untersucht, nämlich: Überlebensrate der Larven, Entwicklungszeit der Larven, Überlebensrate der Puppen, Entwicklungszeit der Puppen, Puppengewicht und Geschlechterverhältnis der Vollkerfe. Als Wirtspflanzen wählte man fünf verschiedene Kreuzblütler, nämlich: *Brassica oleracea* var. *botrytis*, *Brassica pekinensis*, *Sinapis alba*, *Sinapis arvensis* und *Alyssum maritima*, die in Laborversuchen auf ihre Eignung zum Wachstum und zur Entwicklung der Kohlschabe untersucht wurden. Die gefundenen Geschlechterverhältnisse der Vollkerfe wichen nicht signifikant vom erwarteten Wert 1:1 ab, und beim Überleben der Puppen zeigten sich keine ins Gewicht fallenden Unterschiede zwischen den Wirtspflanzen. Die anderen vier biologischen Parameter wiesen erhebliche Unterschiede je nach Wirtspflanze auf, und zwar so, dass die längste Entwicklungszeit der Larven (9,9 Tage), die geringste Überlebensrate der Larven (21,2%), die längste Entwicklungszeit der Puppen (5,6 Tage) und das geringste Puppengewicht (2,6 mg) allesamt auf *Alyssum maritima* festgestellt wurden. Dies führt zu dem Schluss, dass *A. maritima* der Kohlschabe die schlechtesten Möglichkeiten für Wachstum und Entwicklung bietet.

Suchbegriffe: Biologische Parameter, Eignung von Wirtspflanzen, *Plutella xylostella*, Pflanzenfalle.

Introduction

Cruciferous vegetables are important crops throughout the world, comprising up to 25 percent of the land devoted to vegetable planting in some areas (MITCHELL et al. 2000; HARVEY and EUBANKS 2004; PARKER et al. 2013). According to FAO reports, world production of these crops for 2011 was nearly 69 million metric tons, almost half of which produced in China. These crops are staple food of low income people worldwide and also contain high amounts of vitamin C, soluble fiber and multiple nutrients with potent anticancer properties (FAN et al. 2006).

Diamondback moth (DBM), *Plutella xylostella* (L.) (Lep.: Plutellidae), is one of the most damaging insect pests of cruciferous crops worldwide (TALEKAR and SHELTON 1993; BADENES-PEREZ and SHELTON 2006). This pest is feeding specifically on members of the family Cruciferae (THORNSTEINSON 1953; CAPINERA 2001), sometimes causing more than 90 percent crop loss (VERKERK and WRIGHT 1996), and it is estimated to cost the world economy US\$ 4–5 billion annually (FURLONG et al. 2013). Chemical pesticides have dominated attempts to control DBM for a long period. As a consequence this pest developed resistance to many classes of insecticides (TALEKAR and SHELTON 1993; SHELTON et al. 2000; GRZYWACZ et al. 2010). Increase of public concern about pesticides' effects has promoted the interest in non-chemical and sustainable methods (LIM et al. 1996). One of the sustainable control methods is trap cropping which is based mainly on influencing of insect behavior and physiology during searching for and feeding on host plants (HOKKANEN 1991; SRINIVASAN and MOORTHY 1991; MITCHELL et al. 2000).

Herbivorous insects use a wide variety of means to differentiate among host and non-host plants. Trap crops are influencing host-finding behavior to mislead pest or hide host plant (THOMPSON and PELLMYR 1991; PARKER et al. 2013). Host-hiding is achieved through mechanisms such as masking, camouflaging, blocking main crop, or drawing pests away from the main crop. When mechanism of host-hiding is drawing pests away from the main crop, either pest should be destroyed on trap crop or trap crop should not support pest offspring development (PARKER et al. 2013). The term dead-end trap crop has been coined for trap crops which draw pest away from the main crop and do not support its offspring development. Pests on dead-end trap crops face difficulties such as prolonged developmental time and less fitness, fecundity, longevity and survival which in turn will be resulted in low population in next generations. In fact dead-end trap crops exhibit a low preference–performance correlation and serve as a sink rather than a source for subsequent generations (SHELTON and NAULT 2004; DE GROOT et al. 2005).

Since DBM feed specifically on cruciferous members, many cultivated and weedy plants of this family such as *Brassica juncea* (Charleston and Kfir, 2000), *Brassica oleracea* var. *acephala* (MITCHELL et al., 2000), *Alyssum maritima* (de GROOT et al., 2005), *Barbarea vulgaris* (BADENES-PEREZ et al., 2005 and 2014) have been investigated in order to find a proper trap crop for reducing diamondback moth damage. Now, it is a time to study and compare host plant attractivity and suitability for this pest in a fine and exact level to select the proper trap crops and understand their pest suppressing mechanisms in more details. Hereby, this laboratory study was conducted to evaluate impact of five different cruciferous host plants on some biological parameters of DBM in order to estimate their suitability and potential as a trap crop.

Materials and Methods

A) Growing of plants

Seeds of host plants including cauliflower (*B. oleracea* var. *botrytis*), Chinese cabbage (*B. pekinensis*), White mustard (*S. alba*), wild mustard (*S. arvensis*) and sweet alyssum (*A. maritima*) were sown inside plastic pots (diameter: 10 cm, height: 12 cm). Plants were grown in controlled conditions (25 ± 5 °C, $65 \pm 5\%$ RH and L: D 16:8 h) and no fertilizer and pesticide were applied on them (KARIMZADEH et al. 2004; SARFRAZ et al. 2007). Leaves of four to six-leaf stages were used to conduct experiments.

B) Rearing of insects

The original population of diamondback moth was collected from Plant Protection Division of Isfahan Research Center for Agriculture and Natural Resources. This population mass-reared on whole plant of three-week old Chinese cabbage at controlled conditions (25 ± 0.5 °C, $65 \pm 5\%$ RH and L: D 16:8 h). Adult insects were always provided cotton wads with 20% honey solution. In order to have enough same-aged neonate larvae for conducting experiments, adult insects were provided Chinese cabbage plants only for 12 hours and then removed. Same batch of eggs maintained to hatch and enough same-aged larvae emerge to conduct experiments.

C) Conducting of experiments

Experiments designed in a completely randomized design (CRD) with five treatments. Each treatment replicated eight times and ten same-aged neonate larvae were released in each replication. Treatments were five different host plants including cauliflower, Chinese cabbage, white mustard, wild mustard and sweet alyssum. Plant leaves picked up at four to six-leaf stage and cut in same shape and size (discs with 6 cm diameter) and put in Petri dishes. Ten same-aged neonate larvae released on each leaf disc in a Petri dish. Each 24 hours Petri dish cleaned, leaf discs replaced by new and fresh one and larvae were inspected. This procedure was continued up to pupation and larval survival and developmental time were noted down for each treatment and respected replication. Then, pupae weighed in each replication and average pupal weight of each replication was recorded. Each pupa was kept in a ventilated tube up to adult emergence to evaluate pupal survival and developmental time for each replication and treatment. At the end, sexuality of emerged adults were inspected and noted down.

D) Analysis of data

Data analyzed by log linear analysis of deviance. Where there was over dispersion, instead of Poisson error the quasi Poisson was used and the comparison of mean was done by honestly significant different (HSD) and Tukey's test. All statistical analyses were completed in R 2.10.0 (CRAWLEY 2005, 2007).

Results

A) Larval and pupal developmental time

Developmental time of larvae showed a significant difference on different host plants ($t_{15} = 3.637, p < 0.01$). Larval developmental time on *A. maritima* (9.9 days) was much longer than larval developmental time on other host plants including *S. arvensis*, *S. alba*, *B. oleracea* var. *botrytis* and *B. pekinensis* which was 7.6, 6.9, 6.8 and 6.7 (days), respectively. Although pupal developmental time was different among host plants, but significant difference was only seen between *A. maritima* and *B. oleracea* var. *botrytis* (Table 1).

B) Larval and pupal survival

Larval survival showed a significant difference on different host plants ($t_{15} = 3.637, p < 0.01$). Larval survival on *A. maritima* (21.2 %) was much less than larval survival on other host plants including *S. arvensis*, *S. alba*, *B. oleracea* var. *botrytis* and *B. pekinensis* which was 66.2, 80, 83.8 and 91.2 %, respectively. On the contrary, there was no difference among pupal survival on different host plants (Table 2).

C) Pupal weight

Pupal weight on *A. maritima* was significantly less than pupal weight on other host plants. There was no difference among pupal weight on the other host plants (Table 3).

D) Adult sex ratio

Although the observed adult sex ratios on all different host plants were apparently biased towards maleness but statistically had no significant difference from the expected ratio of 1:1 (Table 4).

Discussion

Cruciferous crops are staple food of low income people and DBM is the most destructive insect pest of these crops throughout the world (BADENES-PEREZ et al. 2004). This pest has capability to develop resistance to all insecticide classes and it has been ranked in the top twenty resistant insects worldwide (SARFRAZ and KEDDIE 2005). Therefore, non-chemical methods which could affect pest performance and population dynamics have attracted huge attention to manage this pest.

Life history and population dynamics of DBM can be influenced by various factors, such as environmental conditions and host plant characteristics (GOLIZADEH et al. 2009). Two host plant characteristics, attractivity to ovipositing adults (preference) and suitability for pest growth and development (performance), are of great importance for influencing pest life history and population dynamics (de GROOT et al. 2005). Theoretically, adult females should oviposit on host plants that insure the best survival of their offspring (AWMACK and LEATHER 2002). However, the available data shows a wide range of positive to zero correlations between adult preference and offspring performance (BERTHEAU et al. 2009; AFSANEH et al. 2011). Plants with low or no preference-performance correlation can act as a dead-end trap for DBM. Host plant suitability is affecting development, survival and fecundity of DBM (SARFRAZ et al. 2007). In present study, suitability of five host plants investigated for DBM through measuring larval and pupal development and survival. Also, pupal weight and adult sex ratio were measured as parameters which could influence pest fecundity.

First of all, pupal parameters were different only on *A. maritima* in such a way that the longest pupal developmental time (5.6 days) and the least pupal weight (0.0026 g) observed on *A. maritima* (Tables 1 and 3). In spite of pupal parameters, larval parameters was significantly different among most of tested host plants. The longest larval developmental time (9.9 days) and the lowest larval survival (21.2%) observed on *A. maritima* (Tables 1 and 2).

The observed adult sex ratios had an apparent biased towards maleness on all tested plants, but statistical analysis showed that there was no significant deviation from the expected ratio of 1:1 (table 4). As a matter of fact, adult sex ratio in present study could not be judged decisively due to the following reasons. 1) Since most of larvae and pupa died in the course of experiments, the obtained adult numbers were not enough for a referable analysis. 2) Since effect of host plant on adult sex ratio could be a consequence of sex-biased egg laying of parents or sex-biased survival of offspring, insect should have been reared on same plant species for successive generations which was not done for all tested host plants.

Pest performance was mostly affected on host plant *A. maritima* and its effect on all biological parameters was in the same direction to suppress the pest. The most promising

affected biological parameter was larval survival on *A. maritima* in such a way that nearly 80 percent of larvae died and only 20 percent succeeded to pupate. Survivors had long developmental time (14 days) and their resultant pupae had less weight (2.6mg). Therefore, results clearly indicated that *A. maritima* had low suitability for DBM larvae. In addition to direct impact on individual performance, host suitability can also influence population dynamics (de GROOT et al. 2005). Positive correlation between larval weight and female fecundity of DBM has been proved (BEGUM et al. 1996). As this is probably also true for the relation between pupal weight and fecundity, females reared on *A. maritima* would be less fecund which in turn could lead to decreased population. On the other hand, host suitability not only influence population dynamics within the species, but also can have an impact on the third trophic level. Naturally, low host plant suitability leads to a prolonged developmental time which in turn will be resulted to the longer exposure time to natural enemies. As a result, *A. maritima* has potential to be used as a trap crop to reduce DBM damage in cauliflower and Chinese cabbage farm.

Discussion of other host plants excluded because more or less there was no significant difference between their host suitability compare to cauliflower.

Finally, attention should be paid that these experiments conducted in a laboratory condition on plant leaf discs. These conditions are different from whole and intact plants in farm conditions (ALBORN et al. 1997; KARBAN and BALDWIN 1997). It is necessary to repeat experiments on whole plants in glasshouse and farm conditions for more verification and confidence.

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Table 1: Larval, pupal and larval + pupal developmental time of *Plutella xylostella* on different trap crops

Developmental time (mean \pm SE: days)			
Trap crops	Larval	Pupal	L ₁ -Adult
<i>Alyssum maritima</i>	9.9 \pm 0.4 a	5.6 \pm 0.2 a	14.0 \pm 0.8 a
<i>Sinapis arvensis</i>	7.6 \pm 0.2 b	5.3 \pm 0.1 ab	11.4 \pm 0.3 b
<i>Sinapis alba</i>	6.9 \pm 0.2 bc	5.0 \pm 0.3 ab	10.5 \pm 0.2 b
<i>Brassica oleracea</i> var. <i>botrytis</i>	6.8 \pm 0.2 bc	4.7 \pm 0.1 b	10.2 \pm 0.2 b
<i>Brassica pekinensis</i>	6.7 \pm 0.1 c	4.9 \pm 0.1 ab	10.1 \pm 0.1 b

Means followed by the same letter within the same column are not significantly different (P<0.05, Tukey).

Table 2: Larval, pupal and larval + pupal survival of *Plutella xylostella* on different trap crops

Survival (mean \pm SE: %)			
Trap crops	Larval	Pupal	L ₁ -Adult
<i>Alyssum maritima</i>	21.2 \pm 3.5 a	70.6 \pm 2.5 a	15.0 \pm 3.3 a
<i>Sinapis arvensis</i>	66.2 \pm 4.2 b	66.0 \pm 6.6 a	43.8 \pm 4.2 b
<i>Sinapis alba</i>	80.0 \pm 4.2 bc	75.0 \pm 3.7 a	60.0 \pm 4.2 bc
<i>Brassica oleracea</i> var. <i>botrytis</i>	83.8 \pm 5.6 bc	83.6 \pm 3.7 a	70.0 \pm 5.7 c
<i>Brassica pekinensis</i>	91.2 \pm 4.0 c	72.6 \pm 6.2 a	66.2 \pm 6.0 c

Means followed by the same letter within the same column are not significantly different (P<0.05, Tukey).

Table 3: Pupal weight of *Plutella xylostella* on different trap crops

Trap crops	Pupal weight (mean \pm SE: gram)
<i>Alyssum maritima</i>	0.0026 \pm 0.002 b
<i>Sinapis arvensis</i>	0.0032 \pm 0.001 a
<i>Brassica oleracea</i> var. <i>botrytis</i>	0.0039 \pm 0.002 a
<i>Brassica pekinensis</i>	0.0039 \pm 0.001 a
<i>Sinapis alba</i>	0.0041 \pm 0.002 a

Means followed by the same letter within the same column are not significantly different (P<0.05, Tukey).

Table 4: Adult sex ratio of *Plutella xylostella* on different trap crops

Trap crops	Observed frequency		Expected frequency		χ^2
	male	female	male	female	
<i>Alyssum maritima</i>	6	1	3.5	3.5	3.571
<i>Sinapis alba</i>	22	11	16.5	16.5	3.670
<i>Brassica pekinensis</i>	16	9	12.5	12.5	1.960
<i>Sinapis arvensis</i>	19	13	16	16	1.125
<i>Brassica oleracea</i> var. <i>botrytis</i>	21	19	20	20	0.100

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