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Differential Effects of Food Plants on the Development, Egg Production and Feeding Behaviour of the Diamondback Moth (*Plutella xylostella* L.)

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ABSTRAK

Satu kajian telah dijalankan terhadap perbezaan kesan tumbuhan makanan pada perkembangan larva dan pupa rama-rama belakang intan (DBM) (Plutella xylostella L.) *kelakuan memakan oleh larva dan penghasilan telor oleh serangga dewasa betinanya. Tumbuhan makanan yang diguna adalah lima tumbuhan Brassicaceae (Brassica juncea Cosson, B. juncea Cosson var. rugose Bally, B. alba Rebenh, B. oleracea var. alboglabra Bally and B. juncea L. (Czern)) dan satu Capparidaceae (Cleome rutidosperma DC). Masa perkembangan DBM larva atau pupa adalah dikesani secara bererti oleh tumbuhan makanan. Masa perkembangan larvae adalah lebih panjang (10.9 hari) dan bererti apabila diberi makan B. alba (tumbuhan tanaman) dibandingkan apabila larva diberi makan tumbuhan lain. Walau bagaimana pun, tumbuhan makanan liar menyebabkan masa perkembangan DBM pupa lebih panjang dibandingkan apabila tumbuhan ditanam diberikan sebagai makanan larvae. Perhubungan di antara bilangan telor bagi setiap DBM dewasa betina dengan berat pupa (terbentuk daripada larvae diberikan tumbuhan makanan yang berbeza) adalah kuat (r = 0.85). B. juncea mungkin merupakan tumbuhan makanan yang lebih baik (kualiti makanan yang baik) kerana ia menyebabkan berat pupa and bilangan telor yang terhasil adalah lebih tinggi dibandingkan apabila tumbuhan makanan lain (liar atau ditanam) diberi sebagai makanan DBM larvae. Di dalam ujian tiada pilihan, DBM larvae telah mengambil masa yang lebih lama dan bererti untuk sampai kepada B. juncea (liar dan tanaman) dibandingkan dengan masa yang diambil untuk sampai kepada tumbuhan makanan yang lain. Ini menunjukkan kedua-dua tumbuhan makanan tadi mempunyai kurang sebatian kimia penarik pemakan (larvae). DBM larvae mengambil masa yang lebih pendek dan bererti apabila memakan C. rutidosperma dan B. juncea (tanaman) dibandingkan dengan masa yang diambil untuk memakan tumbuhan makanan lain. Di dalam ujian pilihan pula, DBM larvae mengambil masa yang sama panjang untuk sampai kepada semua tumbuhan makanan. Namun begitu, mereka telah mengambil masa yang lama dan bererti untuk memakan B. juncea dibandingkan dengan tumbuhan makanan lain. Potensi C. rutidosperma untuk diguna dalam pengurusan DBM yang rintang terhadap racun serangga juga dibincangkan.*

ABSTRACT

Differential effects of food plants on developmental time of diamondback moth (DBM) (Plutella xylostella L.) larvae and pupae, larval feeding behaviour and egg production by the adult were studied. The food plants used were five Brassicaceae plants (Brassica juncea Cosson, B. juncea Cosson var. rugose Bally, B. alba Rebenh, B. oleracea var. alboglabra Bally and B. juncea L. (Czern)) and one Capparidaceae (Cleome rutidosperma DC). The developmental times of DBM larvae and pupae were significantly affected by the food plants. Larval developmental time was significantly longer (10.9 days) when fed on B. alba (cultivated) than on the other food plants. The wild food plants seemed to prolong the developmental time of DBM pupae compared with the cultivated hosts. There was a strong relationship (r = 0.85) between the numbers of eggs laid by DBM adults and the weight of the pupae which developed from larvae fed on various food plants. In contrast to the wild hosts and three other cultivated hosts, B. juncea seemed to be a better food plant (better quality food) as it caused higher pupal weight and egg production by the female adults. In a no-choice test, DBM larvae took a significantly longer time to reach

B. juncea (wild and cultivated) than other host plants, indicating that the former had fewer feeding attractants. DBM larvae spent significantly shorter time to feed on C. rutidosperma and cultivated B. juncea than on other food plants. In a choice test, DBM larvae took about equal amounts of time to reach each food plant. However, they spent significantly longer time feeding on B. juncea than on other food plants. The potential of C. rutidosperma to be used in insecticide-resistant management of DBM is also discussed.

INTRODUCTION

The diamondback moth (DBM) (*Plutella xylostella* L.) is a major pest of *Brassica* crops worldwide (Harcourt 1986). It is one of a few insect pest species that have developed resistance to all pesticides, including *Bacillus thuringiensis* (Talekar and Shelton 1993). It can be found on many Brassicaceae plants (main host or food) and certain non-host plants containing mustard oils (glucosinolates) (Marsh 1917; Thorsteinson 1953; Gupta and Thorsteinson 1960). The abundance of host plants is a key factor in determining the survival rate and population dynamics of DBM and its natural enemies (Marsh 1917; Harcourt 1986; Fox *et al.* 1990; Eigenbrode and Shelton 1992; Hough-Goldstein and Hahn 1992; Ooi 1992; Talekar and Shelton 1993). The presence of different types and concentrations of glucosinolates, which act as feeding attractants or stimulants, between host plants was identified by Cole (1976).

The possible impact of *Brassica vulgaris* R. BR. and *Brassica kaber* D.C. Wheeler on resistance management of DBM in Michigan, USA, was reported by Idris and Grafius (1994, 1996a, b). In India, the Indian mustard (*Brassica juncea* (L.) (Czern.), has been used successfully as a trap crop for controlling DBM (Srinivasan and Krishna Moorthy 1991). A study on the impact of *Cleome rutidosperma* DC (Capparidaceae) on cabbage webworm (CWW), *Hellula undalis* (F.), conducted in Malaysia indicated that this weed is a suitable food plant for CWW (Sivapragasam *et al.* 1994). The objectives of this study were to assess the differential effects of *C. rutidosperma* and *Brassica* host plants on the developmental times of DBM larvae and pupae, larvae feeding behaviour, and egg production of adult females.

MATERIALS AND METHODS

Insect and Host Plant Sources

First generation UPM-resistant strain DBM donated by Malaysian Research Development Institute (MARDI) was used for the study. Four cultivated *Brassica* (*B. juncea* Cosson, *B. alba* Rebenh, *B. juncea* Coss. var. *rugose* Bally, *B. oleracea* var. *alboglabra* (Bally), one wild *Brassica* (*B. juncea* L. (Czern)(Indian Mustard), and one Capparidaceae (*Cleome rutidosperma* DC) were used as DBM food plants. These food plants were raised in clay pots in the greenhouse one month prior to the experiment.

Developmental Times and Egg Production

First instar DBM larvae (3-5 h after hatching) were placed in 15-cm diam Petri dishes and fed with a piece of host plant leaf (4 cm^2 per larva per dish). The food was replaced every 2 days to maintain freshness. The treatments (food plants, five replicates per treatment) were arranged following a complete randomized design, and placed in a growth chamber at 25 $\pm$ 2oC, 12:12 h (L:D) photoperiod and 50% relative humidity (RH) until adult emergence. Treatments were checked daily to record the larval and pupal developmental times. Pupae were weighed when the colour had changed from light green to brownish (about 2 days before adult emergence). The emerged DBM adults were kept for 2 - 3 days in a refrigerator (5°C) before being used in a subsequent experiment.

A modified 500-ml plastic container with a screen lid on top (4 x 5 cm) and on the sides (3 x 3 cm), was used as an oviposition cage. A pair of DBM adults was released in each cage placed under white light (CROMPTONR, 160 Watt, and 80 cm above the top cage with light intensity range of 430 - 500 lux) for 2 days, after which the males was taken out, to ensure mating occurred. A 15-ml test tube (3 x 6 cm) filled with 10% (v/v) diluted honey was placed inside the cage to feed the DBM adults. A single piece of aluminium (Al) foil, 2.5 x 4 cm, with strips on both sides made using forçeps, coated with the juice of cabbage leaves (prepared following Idris 1995) was put in a cage through a cut made in the lid to serve as an oviposition substrate. Treatments were replicated four times, arranged following a randomized complete block design (to minimize the effect of light intensity gradient), and kept at room temperature and

RH. The number of eggs was recorded at 0700 h daily, the same time the Al foil was also replaced, until there were no eggs laid.

Feeding Behaviour of DBM Larvae

Choice and no-choice tests were used to study feeding behaviour of DBM larvae on different food plants. In both tests, a modified 15-cm diam Petri dish (four screen lids, 1 cm diam, were made in the cover for better ventilation) was used. The host plants used were two cultivated *Brassica (B. juncea* Cosson and *B. alba* Rabenh) and two weed species, *B. juncea* L. and *C. rutidosperma.* In a no-choice test, three pieces of leaf (2 cm^2 each) of a plant species were placed in each Petri dish (1, 4.5 or 7 cm from the edge, centre or between the pieces of leaf). One third instar DBM larva, starved for 6 h, was released in the centre of a dish. In a choice test, four pieces of leaf (similar size as for no-choice test and each leaf piece representing a plant species) per replicate were placed in the Petri dishes and arranged as for no-choice test, except the distance between leaf pieces was 5 cm. In both tests, treatments were placed 80 cm below the white light as mentioned above, and kept at room temperature and RH. Times taken by the larvae to reach food (leaf piece) from the point of release (centre of dish), and times spent for feeding during 3 hours' observation (1400 - 1700 h) were recorded using a tape recorder.

Data Analysis

To depict the qualitative trend (not for demarcating quantitative differences) between the pupal weight and number of eggs produced data were analysed using regression analysis (Abacus Concepts 1991). The developmental times of DBM larvae and pupae, times taken by larvae to reach food and times spent by larvae for feeding per plant (food) during 3 hours' observation were analysed using one-way analysis of variance (ANOVA) (Abacus Concepts 1991).

RESULTS AND DISCUSSION

Developmental Times and Egg Production

The developmental time of DBM larvae was significantly ($P < 0.05$, Fisher's Protected LSD) shorter when larvae were fed on *B. juncea* var. *rugose* and *B. oleracea* var. *alboglabra* (cultivated) than on the *B. alba* and *B. juncea* (cultivated), and *B. juncea* (Czern.) and *C. rutidosperma* (wild) (Table 1). Interestingly, the developmental time was significantly ($P< 0.05$, Fisher's Protected LSD) prolonged by the cultivated food plant, *B. alba*, and not by the wild food plants, *B. juncea* (Czern) and *C. rutidosperma.* This indicates that host food plants had different effects on the developmental time of DBM larvae, which might be affected by the glucosinolates, because DBM larvae do not discriminate between different types of glucosinolates present in the food plants (Reed *et al.* 1989). The glucosinolates of *Pieris rapae* L.,

TABLE 1
Developmental times of diamondback moth larvae and pupae fed on different food plants

Food Plants	Common Name	Developmental times (day ± S.E)	
		Larva	Pupa[1]
Cultivated			
Brassica juncea Cosson	Sawi	10.10 ± 2.32b	4.62 ± 0.81 ab
B. juncea Cosson var. *rugose* Bally	Kai Choy	9.12 ± 3.11c	4.10 ± 0.56b
B.alba Rebenh	Kai lan	10.87 ± 1.97a	2.34 ± 1.22c
B.oleracea var. *alvoglabra* bally	Sawi Putih	9.38 ± 2.42	4.01 ± 1.56b
Wild			
B. Juncea L. (Czern)	Indian Mustard	9.89 ± 3.13b	4.86 ± 0.78a
Cleome rutidosperma DC[2]	Purple Maman	9.93 ± 2.65b	5.01 ± 0.85a

[1]From start of pupation until adult emergence; [2]Capparidaceace, others are Brassicaceae
Means in column with same letter were not significantly different ($p > 0.05$, Fisher's Protected LSD)

a food plant that acts as an antifeedant, prolonged developmental time of its larvae to pupation (Hough-Goldstein and Hahn 1992).

The developmental time of DBM pupa was significantly (P < 0.05, Fisher's Protected LSD) longer when larvae were fed wild food plants than with cultivated food plants (Table 1). In contrast, the developmental time of *H. undalis* pupae fed on *C. rutidosperma* was significantly shorter than when fed cultivated *Brassica* species (Sivapragasam *et al.* 1994). Some types of glucosinolates of *C. rutidosperma* were reported to slow down the developmental rate of DBM pupae (Gupta and Thorsteinson 1960; Cole 1976; Wallbank and Wheatley 1976).

There was a strong relationship (r = 0.85, P < 0.05) between the number of eggs laid by adult DBM females and the weight of pupae developed from larvae fed on different food plants (*Fig. 1*). DBM larvae fed on *B. juncea* (cultivated) resulted in higher pupal weight and more productive females (laid more eggs) than those fed on other food plants. This suggests that there are qualitative differences between food plants that affect development and reproduction of DBM. A study conducted by Fox *et al.* (1990) also found that the quality of cabbage plants is positively correlated with the size of DBM larvae or pupae.

Feeding Behaviour of DBM Larvae

In a no-choice test, DBM larvae took significantly (P < 0.05, Fisher's Protected LSD) shorter time to reach *C. rutidosperma* and *B. juncea* var. *rugose* than the other food plants (Table 2). In contrast, the time taken by DBM larvae to reach the food sources in a choice test was not significantly (P > 0.05, Fisher's Protected LSD) different among food plants. This suggests that *C. rutidosperma* and *B. juncea* var. *rugose* have higher concentrations of feeding attractants than other food plants (Cole 1976).

The feeding time spent by DBM larvae in 3-hour observation periods was significantly (P < 0.05, Fisher's Protected LSD) longer on the cultivated than on the wild food plants except in a choice test (Table 2), indicating that wild food plants are not good food sources for DBM. In contrast, Thorsteinson (1953) reported that feeding responses, which were measured as feeding activity per unit time, of DBM on the wild food plants (Capparidaceae; *Capparis flexuosa* and *C. spinosa*) was as active as on the cultivated Brassicaceae plants.

Results show that cultivated *B. juncea* was a better food plant of DBM (higher number of eggs produced per adult female, and longer time spent feeding on it) than the other food plants (Table 1 & 2, *Fig. 1*). This suggests that it should not be planted alone if we want to avoid heavy infestation of DBM and reduce pesticide usage. The *C. rutidosperma* and *B. juncea* var. *rugose* (in both tests) might have a higher concentration of glucosinolates that act as feeding attractants compared with wild *B. juncea* as times taken by DBM larvae to reach *C. rutidosperma*

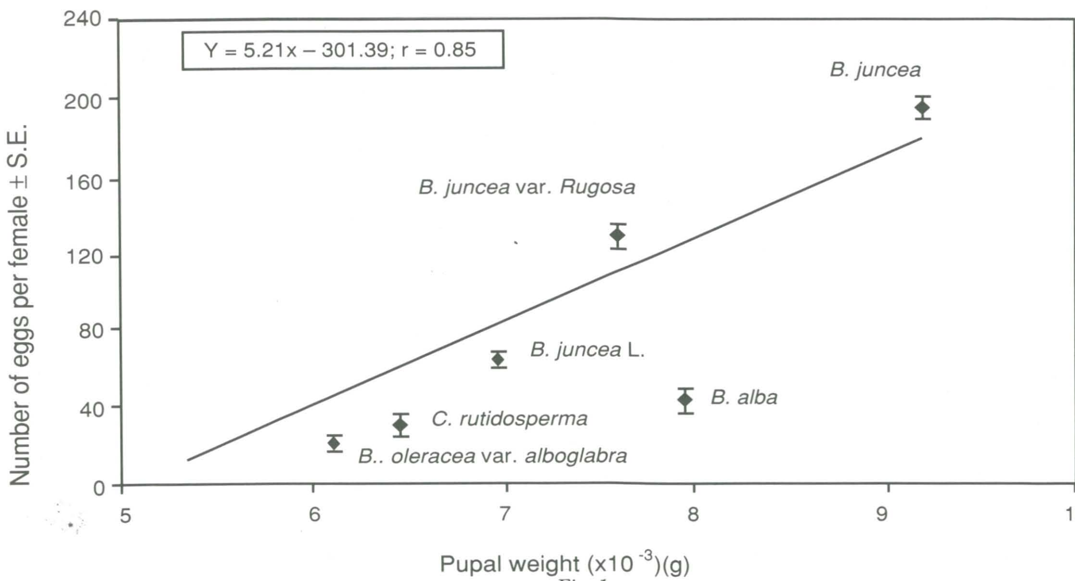

Fig 1

TABLE 2
Time (minutes ± S.E) taken by diamondback moth third instar larvae to (a) reach food and (b) feed in no-choice and choice tests [1,2]

Food Plants	No-choice test		Choice test	
	Reach food	Feed	Reach food	Feed
Cultivated				
Brassica juncea Cosson	28.31 ± 10.32b	30.02 ± 9.01b	4.43 ± 2.10b	35.58 ± 10.13a
B. juncea Cosson var. *rugose* Bally	10.54 ± 3.12c	45.83 ± 8.92a	5.21 ± 2.31b	20.65 ± 5.34b
Wild				
B. Juncea L. (Czern)	50.01 ± 10.67a	15.23 ± 3.50c	5.32 ± 2.05b	10.89 ± 3.54c
Cleome rutidosperma DC	12.43 ± 4.21c	16.54 ± 3.21c	8.93 ± 3.23b	13.75 ± 6.27b

[1]observation was made from 1400 to 1700 h (3 hours)
[2]Means in column with same letter were not significantly different ($p > 0.05$, Fisher's Protected LSD)

and *B. juncea* var. *rugose* were shorter than to wild *B. juncea* (Table 2). However, *C. rutidosperma* or *B. juncea* var. *rugose* might not have or having similar concentration of feeding stimulant as *B. juncea*. There seemed to be no difference in food quality offered by the two wild food plants as the pupal weight and eggs produced per female are somewhat similar (*Fig. 1*). Although *B. oleracea* var. *alboglabra* and *B. alba* seemed to have similar food quality, as indicated by their effect on the pupal weight or numbers of eggs produced by DBM females, the feeding behaviour of DBM larvae on those varieties was not tested.

C. rutidosperma is a ubiquitous weed in Malaysia while wild *B. juncea* was introduced from India (Henderson 1974; Sivapragasam and Loke 1995). Wild *B. juncea* was also proved to possess an oviposition attractant that makes it possible to use it as a trap crop (Srinivasan and Krishna Moorthy 1991). In Malaysia, it is not practical to interplant wild *B. juncea* with *Brassica* crops due to socio-economic reasons (Sivapragasam and Loke 1995). It can be planted around the field and insecticide sprayed only when necessary. This could reduce the population of DBM and other cabbage pests in the field as well as insecticide-resistance development. Unlike wild *B. juncea*, the effect of *C. rutidosperma* on DBM oviposition behaviour has never been studied. We can diverge DBM oviposition activity from the cultivated brassicas, especially near or at the critical growth stages, to *C. rutidosperma* (if it is found to possess oviposition attractant) planted around or within a field. When *C. rutidosperma* is not needed it can easily be pulled out manually; therefore, weedicide use is not necessary. Since cultivated *B. juncea* seemed to be a good food plant for DBM, it should be interplanted with other crops such as tomato. Bach and Tabashnik (1990) reported that DBM infestation was significantly lower in the cabbage field interplanted with tomato plants than in the field planted with cabbage alone. Wild *B. juncea* can also be planted around the plot or field planted with cultivated *B. juncea* , and this may avoid heavy infestation of DBM on cultivated *B. juncea.*

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REFERENCES

ABACUS CONCEPTS. 1991. *SuperAnova.* Berkeley, CA: Abacus Concepts.

BACH, C.E. and B.E. TABASHNIK. 1990. Effects of nonhost plant neighbors on population densities and parasitism rates of the diamondback moth (Lepidoptera: Plutellidae). *Environ. Entomol.* **19**: 987-994.

COLE, R.A. 1976. ISOTHIOCYANATES, nitriles and thiocyanates as products of autolysis of glucosinolates in Cruciferae. *Phytochem.* **15**: 759-762.

EIGENBRODE, S.D. and A.M. SHELTON. 1992. Survival and behavior of *Plutella xylostella* larvae on cabbages with leaf waxes altered by treatment with S-ethyl dipropythiocarbamate. *Entomol. Exp. Appl.* **62**: 139-145.

FOX, L.R., D.K. LETOURNEAU, J. EISENBACH and S.V. NOUHUYS. 1990. Parasitism rates and sex ratios of parasitoid wasp: Effect of herbivore and plant quality. *Oecologia* **83**: 414-419.

GUPTA, P.D. and A.J. THORSTEINSON. 1960. Food plant relationships of the diamondback moth (*Plutella maculipennis* (Curt.)). *Entomol. Exp. Appl.* **3**: 241-250.

HARCOURT, D.G. 1986. Population dynamics of diamondback moth in southern Ontario. In *Diamondback Moth Management. Proceedings of 1st International Workshop,* ed. N.S. Talekar, p. 3-16. Shanhua, Taiwan: Asian Vegetable Research and Development Center.

HENDERSON, M.R. 1974. *Malayan Wild Flowers. Vol. 1: Dicotyledons.* Kuala Lumpur: Malayan Nature Society.

HOUGH-GOLDSTEIN, J. and S.P. HAHN. 1992. Antifeedant and oviposition deterrent activity of a aqueous extract of *Tanacetum vulgare* L. on two cabbage pests. *Environ. Entomol.* **21**: 837-844.

IDRIS, A.B. 1995. Ecology and behavior of *Diadegma insulare* (Cresson), a biological control agent of diamondback moth, *Plutella xylostella* (L.). PhD dissertation, Michigan State University,

IDRIS, A.B. and E. GRAFIUS. 1994. The potential of using *Barbarea vulgaris* in insecticide-resistant diamondback moth management. *Resist. Pest Manag.* **6(2)**: 7-8.

IDRIS, A.B. and E. GRAFIUS. 1996a. Effects of wild and cultivated host plants on oviposition, survival, and development of diamondback moth (Lepidoptera; Plutellidae) and its parasitoid *Diadegma insulare* (Hymenoptera: Ichneumonidae). *Environ. Entomol.* **25**: 825-833.

IDRIS, A.B. and E. GRAFIUS. 1996b. Possible impact of *Barbarea vulgaris* on insecticide-resistant diamondback moth management program. *Resist. Pest Manag.* **8(2)**: 17-20.

MARSH, O.H. 1917. The life history of *Plutella maculipennis,* the diamondback moth. *J. Agric. Res.* **10**: 1-10.

OOI, P.A.C. 1992. Role of parasitoids in managing diamondback moth in the Cameron Highlands, Malaysia, In *Diamondback Moth and Other Crucifers Pests. Proceedings of 2nd International Workshop,* ed. N.S. Talekar, p. 255-262. Shanhau, Taiwan: Asian Vegetable Research and Development Center.

REED, D.W., K.A. PIVNICK and E.W. UNDERHILL. 1989. Identification of chemical oviposition stimulants for the diamondback moth, *Plutella xylostella,* present in three species of Brassicaceae. *Entomol. Exp. Appl.* **53**; 277-286.

SIVAPRAGASAM, A. and W.H. LOKE. 1995. Management of inset pests on cabbage using Indian Mustard, *Brassica juncea* (L.) (Czern.) as a trap crop. In *Proceedings of the AVNET II Midterm Workshop,* p. 245-246. AVRDC Publication no. 95-438, Shanhau, Taiwan: Asian Vegetable Research and Development Center.

SIVAPRAGASAM, A., A. ASMA and M.A. RAFI. 1994. Development and biotic potential of cabbage webworm (*Hellula undalis*) on the weed, *Cleome rutidosperma.* Paper presented *at International Conference on Plant Protection in the Tropics,* 23-31 March 1994, Kuala Lumpur, Malaysia.

SRINIVASAN, K. and P.N. KRISHNA MOORTHY. 1991. Indian mustard as a trap crop for management of major lepidopterous pests on cabbage. *Trop. Pest. Manag.* **37**: 26-32.

TALEKAR, N.S. and A.M. SHELTON. 1993. Biology, ecology and management of the diamondback moth. *Ann. Rev. Entomol.* **38**: 275-301.

THORSTEINSON, A.J. 1953. The chemotactic responses that determine host specificity in a oligophagous insect (*Plutella maculipennis* Curt.) (Lepidoptera). *Can J. Zool.* **31**: 763-766.

WALLBANK, B.E. and G.A. WHEATLEY. 1976. Volatile constituents from cauliflower and other crucifers. *Phytochem.* **15**: 763-766.

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