Plutella xylostella larval feeding effects on three forage brassica species: kale, rape and turnip

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Abstract Diamondback moth (*Plutella xylostella*) (DBM) is a major pest of forage brassica crops in New Zealand. This study evaluated the effects of DBM larval feeding on three forage brassica crops in a greenhouse experiment. DBM eggs in batches of 5, 10 or 50 were placed on 6-week-old potted kale, rape and turnip plants. Plant growth and development (main stem diameter, plant height, total number of stems and leaves, and dry matter weight of roots and foliage (including stems)) were measured at harvest. Additionally, the number of pupae recovered was recorded. None of the measurements of plant growth was influenced ($P > 0.05$) by DBM egg density. Percentage pupal recovery was consistent between treatments. Larger DBM population sizes may have been required to show an effect on plant growth. Implications of these results for DBM pest management are discussed.

Keywords diamondback moth, *Plutella xylostella*, *Brassica oleracea* spp. *acephala*, *Brassica napus* spp. *biennis*, *Brassica rapa*, *Brassica campestris*, forage brassicas.

INTRODUCTION

Diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera:Plutellidae), is a key pest of brassicas both worldwide and in New Zealand (Talekar & Shelton 1993; Cameron et al. 1997). The larvae feed on host leaves and growing tips creating typical 'window-paning' damage associated with its presence (Beck 1991). The estimated worldwide annual management cost for this pest was reported to be around US \$1 billion in the early 1990s (Talekar & Shelton 1993) in addition to being responsible for significant crop losses. DBM is hard to manage because: (i) its genetic elasticity has made it resistant to most insecticides applied in the field; (ii) the primary brassica host plants are widely grown; and (iii) the use of broad-spectrum insecticides contributes to

the suppression of its natural enemies (Talekar & Shelton 1993; Sarfraz et al. 2006).

In New Zealand, approximately 300,000 ha of forage brassicas are grown (Walker et al. 2011), with most of the production occurring in the South Island (White & Hodgson 1999). They are primarily used for winter feeding of livestock, and are also used to supplement pasture at other times of the year (de Ruiter et al. 2009). Forage brassicas provide high quality feed when the pasture growth and quality is poor during mid-summer and winter (Stewart & Charlton 2003). They also have a role as break crops in pasture renewal. Kale (*Brassica oleracea* spp. *acephala*), rape (*B. napus* spp. *biennis*) and turnip (*B. rapa*; syn. *B. campestris*) are the main forage species

grown in New Zealand. These are all host plants for DBM. Many studies have focussed on the impact of host plants on the pest (Rossbach et al. 2006; Sarfraz et al. 2007; Sarfraz et al. 2009; Badenes-Pérez et al. 2011; Henniges-Janssen et al. 2010; Sarfraz et al. 2011). The few studies that have examined the effect of the pest on the host plant have been on non-forage species (e.g. vegetable brassicas and oil seed rape) (Sarfraz et al. 2007; Sarfraz et al. 2009). Brassica crops bred for forage or vegetable consumption have been developed with differing selection criteria and therefore their responses to insects may be different. Vegetable brassica crops are primarily managed for quality with lesser emphasis on yield. High biomass yield is important for forage crops being fed to cattle and sheep. Crop management that supports high yield may strongly affect the development of pest populations.

In this study, the effect of DBM larval feeding on the growth and development of three forage host species (kale, rape and turnip) was evaluated to determine the effects of potential population pressure on host plant biomass.

MATERIALS AND METHODS

Plant material

The three species of forage brassicas used were: kale (*Brassica oleracea* spp. *acephala*, cv. 'Gruner'), rape (*B. napus* spp. *biennis*, cv. 'Goliath') and turnip (*B. rapa*; syn. *B. campestris*, cv. 'Barkant'). Seeds of each species were sown in seed trays and placed in a growth chamber at 22°C ($\pm 1^\circ\text{C}$) and 16:8 h light:dark (L:D). Six days after sowing, seedlings were transferred to 10-litre pots with one plant per pot. The potting mix consisted of three parts of shredded bark (*Pinus radiata* D. Don.) to two parts of washed crusher sand, supplemented with 3 kg/m³ dolomite lime, 3 kg/m³ "Osmocote 15–9–12", 1.8 kg/m³ garden lime, 1.35 kg/m³ Zeolites, 1.05 kg/m³ superphosphate, 300 g/m³ calcium nitrate and 300 g/m³ sulphate of potash. Plants were then grown under glasshouse conditions, at 20°C ($\pm 2^\circ\text{C}$) and 16:8 h L:D, and watered from above. Water and nutrients for plant growth were not limiting and plants were monitored regularly for

other pests and diseases that may have interfered with the DBM treatments.

Insect material

DBM eggs were manually applied to plants to simulate DBM infestation. Eggs came from a DBM laboratory colony maintained at the New Zealand Institute for Plant & Food Research (Auckland) that had been derived from insects collected in April 1993 at Pukekohe Research Station (South Auckland) from cabbage fields that had not been sprayed with insecticides for at least 4 years prior to collection. Insects were reared on cabbage plants in a controlled temperature room at 18–25°C and 16:8 h L:D and without exposure to insecticides. Eggs were collected on foil sheets 2–3 weeks before use and were kept at 4°C ($\pm 2^\circ\text{C}$) until treatments were applied.

DBM larval feeding effects on plant growth

The effect of different densities of DBM larvae feeding on plants was assessed by applying different egg densities to the three forage brassica species. Egg densities were: 5, 10 or 50 eggs per plant, with a 0 egg control for each brassica species. Four replicates of the 12 treatment combinations (3 species $\times$ 4 egg densities) were laid out in a 4 $\times$ 12 array of pots, according to a latinized resolvable incomplete block design. Eggs were positioned on the plant growing tip at 6 weeks (replicates 1 and 2) and 7 weeks (replicates 3 and 4) after sowing to simulate as much damage as possible. Plants were then encased within clear open-top acetate cylinders (1 m height, 40 cm diameter) to prevent larvae from moving from one plant to another. After 1 week, the plants were monitored daily for pupae, and once found, these were counted and removed to prevent DBM adult emergence and to simulate one lifecycle only. Cylinders were removed when no more pupae were found on plants. Plants were harvested at recommended grazing maturity (except for kale, which was harvested 2 weeks before maturity). Turnip was harvested 70 days after sowing. Rape was harvested 105 (replicates 1 and 2) and 108 (replicates 3 and 4) days after sowing. Kale was harvested 111 (replicates 1 and

2) and 112 (replicates 3 and 4) days after sowing. Measurements at harvest included root dry matter weight, foliage dry matter weight (including stem), main stem diameter, plant height, total number of leaves, and total number of stems. Main stem diameter was measured at the root/shoot junction using a calliper (Sarfraz et al. 2009). Plant height was measured from ground level to the growing tip.

Statistical analyses

Analyses of all parameters were conducted separately for each species. All parameters except pupae numbers were analysed with analysis of variance. Data for the zero applied egg treatment were excluded from the analyses of pupae numbers, as no pupae were found on those plants. The number of pupae recovered as a percentage of the number of eggs applied was analysed with a standard binomial GLM with a logit link (McCullagh & Nelder 1989). Mean percentages along with 95% confidence limits were obtained on the logit link scale, and back-transformed to percentages. All analyses were carried out with GenStat (GenStat Committee 2011).

RESULTS

For all plant response variables there was no significant effect ($P>0.05$) of DBM egg density. This was true for all brassica species tested (Figure 1). There was, however, a marginal effect of egg density on foliage dry weight for turnip ($P=0.085$). This leaf biomass measurement was lower with 5 and 50 egg batches than with either 0 or 10 eggs (Figure 1e). There was a similar weak effect on plant height for turnip ($P=0.079$), with plants slightly taller with 10 eggs and shorter with 50 eggs than for the other egg densities (Figure 1c).

Larval feeding did not affect stem number as no branching or tillering was observed in any species.

The percentage of DBM eggs recovered as pupae over the course of this experiment was generally 40% or above (Figure 2), and this percentage did not vary significantly with egg density for any of the species ($P>0.100$). However, there was a poor recovery from turnip at the egg density of 5.

DISCUSSION

The growth of forage brassica species and cultivars tested in the current glasshouse study was not substantially affected by feeding damage from a single generation of DBM larvae, even at the maximum egg density (50). However, plant to plant variability in the measurements recorded was high. This occurred in all species but was more prevalent for kale and rape than for turnip. The results do suggest that larval survival to pupae was not affected by the number of eggs applied or the plant species.

Previous work has shown damaging effects of DBM feeding on plant growth (Sarfraz et al. 2007, 2009). The plant growth variables used in the present study (especially root dry matter weight and main stem diameter) were chosen based on this previous work, where the authors found that these variables were affected by DBM feeding on non-forage cultivars of rape, turnip and kale. Furthermore, Sarfraz et al. (2007, 2009) found that turnip was more susceptible than kale or rape to defoliation by DBM larvae, a result that was consistent with the observable but not significant trends in this study. However, the results of Sarfraz et al. (2007, 2009) contrast with New Zealand field observations that suggest that turnip is tolerant to DBM (G.P. Walker, Plant & Food Research, personal communication). In contrast to the results obtained with turnip, Sarfraz et al. (2007, 2009) also found that rape infested with DBM larvae had heavier root systems than uninfested rape, while kale roots were unaffected. In the present study, no effect of DBM feeding was found on the root systems of rape plants.

There were differences in the experimental setup used in the present study compared with the one used by Sarfraz et al. (2007, 2009). Eggs were positioned on plants at 6 to 7 weeks after sowing, while Sarfraz et al. (2007, 2009) applied larvae on 4-week-old plants, which allowed more larval feeding on less plant material. Applying the eggs when the plants were younger and therefore more susceptible may have given more significant results. Also, DBM egg densities used in the present experiment may have been

Figure 1 Mean value for each plant measurement at different numbers of eggs applied for kale, rape and turnip. (a) Main stem diameter (mm), (b) Number of leaves, (c) Plant height (cm), (d) Root dry matter weight and (e) Foliage dry matter weight. Error bars are LSD ($P=0.05$; $df=9$) for each forage brassica species.

Figure 2 Percentage pupae recovered at different numbers of eggs applied. Error bars are 95% confidence limits for the means for each forage brassica species for 5 and 50 applied eggs only, obtained from separate analyses of the data for each species.

inadequate; up to 500 DBM larvae per plant have been observed in the field (G.P. Walker, Plant & Food Research, personal communication). Additionally, the high plant-to-plant variability recorded here suggests a greater number of replicates may be required to record the impact of larval feeding on plant yield. If the impact of a single generation of up to 50 DBM larvae is negligible, on kale and rape in particular, this suggests that the plants infested at this growth stage can compensate and 'outgrow' such feeding damage. However, this capacity to outgrow the insect infestation may be relevant only under ideal conditions similar to those maintained in the present study: 20°C ($\pm 2^\circ\text{C}$), 16:8 h L:D, no water or nutrient limitation, and no stress from other pests or pathogens. In the field, there is possibly less tolerance to DBM populations before the effects on the whole plant are manifest. Furthermore, the maximum number of DBM per plant that forage brassicas can tolerate, before intervention with insecticides is required, may be higher than for vegetable brassicas (Walker et al. 2009). Further experimentation is necessary to determine thresholds for larval populations of DBM for forage brassicas under field conditions.

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