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Impact of grasshopper feeding on selected cultivars of cruciferous oilseed crops

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Abstract

With the trend towards crop diversification, there has been a gradual increase in production of crucifer oilseed crops (canola and mustard) in the Prairie Ecozone of western Canada. Developments in germplasm of *Brassica* spp. and *Sinapis alba* L. have resulted in cultivars with improved drought resistance, making them more acceptable for production in arid regions of the prairies. This, in turn, has resulted in increased overlap in areas of grasshopper infestation and oilseed production. Grasshoppers are the most chronic insect pests of annual crops in the Prairie Ecozone. The primary threat to production of annual crops arises from migration of the hatchling populations into cropland from roadsides, headlands and field margins at the beginning of the growing season. As a result, grasshopper damage is most acute at the early stages of crop growth.

In this study, the impact of early season grasshopper feeding on canola and mustard crops was quantified in field studies, 1996 to 1998. Immatures of *Melanoplus sanguinipes* (the lesser migratory grasshopper) were allowed to damage eight Brassicaceae cultivars and breeding lines of four species: *Brassica juncea* Czern ('AC Vulcan' and 'J92-223'), *B. napus* ('AC Excel' and 'Midas'), *B. rapa* ('AC Parkland' and 'Echo') and *S. alba* ('AC Pennant' and 'Ochre'). The overall yields of defoliated plants were 27.8% less than those of control plants (p = 0.0001). Yield reductions were greatest for AC Excel (47%) and least for AC Vulcan (19.6%). The results are discussed in the context of grasshopper management strategies.

Key words

Pest management, grasshoppers, plant damage, yield loss, oilseed crucifers

Introduction

Annual crops, predominantly small-grain crops, occupy approximately 60% of the 50 million ha of the Prairie Ecozone, a northern extension of the Great Plains of North America (Anonymous 1997). With the trend towards crop diversification, there has been a gradual increase in production of crucifer oilseed and condiment crops (canola and mustard) on the prairies at the expense of cereal crop production. The two canola species, *Brassica napus* and *B. rapa*, are processed for cooking oil. There are three mustard types, derived from two species, *B. juncea* and *S. alba*. Yellow mustard (*S. alba*) is grown for the North American condiment market. Brown mustard (*B. juncea*) is grown for the European condiment market. In addition, select cultivars of oriental mustard (*B. juncea*) are grown for cooking oil. Developments in germplasm of *Brassica* and *Sinapis* have resulted in cultivars with improved drought resistance, making them more acceptable for production in the more arid regions of the prairies. This, in turn, has resulted in increased overlap in areas of grasshopper infestation and oilseed production.

Grasshoppers have long been a feature of prairie agriculture (Riegert 1980); however, only a small proportion of the more than 90 species described by Brooks (1958) in this region are of recurring economic importance. The major economically important species are *Melanoplus sanguinipes* (Fabr.), *M. bivittatus* (Say) and *M. packardii* (Scudder) and *Camnula pellucida* (Scudder). These four species have one generation per year, overwintering as eggs in the soil on the Prairie Ecozone. As the soil warms in spring, the eggs hatch and the nymphs emerge by April or May. The nymphs develop through five instars and reach adulthood in July.

Grasshoppers are the most chronic insect pests of small-grain and oilseed crops in the Prairie Ecozone. The primary threat to production of annual crops arises from migration of the hatchling populations into cropland from roadsides, headlands and field margins, favored oviposition sites for these species. Due to the high concentration of eggs at these oviposition sites, grasshopper densities are often very high at the time that early instars disperse from these grassy areas into the cropland. As a result, grasshopper damage is most acute when grasshopper hatch is synchronized with seedling emergence. However, defoliation can occur at all stages of plant growth (Olfert 1987) and at plant maturity (McBean & Platt 1951). The impact of grasshopper feeding on cereals (Olfert 2000) and pulse crops (Olfert & Slinkard 1999) is well documented; however, the impact on oilseed crops in early season has not been elucidated.

The objective of this study was to quantify the impact of grasshopper defoliation on young canola and mustard plants and to determine whether there are significant differences in the response to feeding damage within the different oilseed and condiment crop species.

Materials and Methods

The study was conducted from 1996-1998 at the Agriculture and Agri-Food Canada Research Centre Farm at Saskatoon, SK. Eight cultivars (cv.) from four species were studied: *Brassica juncea* (L.) Czern. ('AC Vulcan' and 'J92-223'), *B. napus* L. ('AC Excel' and 'Midas'), *B. rapa* L. ('AC Parkland' and 'Echo') and *Sinapis alba* L. ('AC Pennant' and 'Ochre').

In the preceding October, field plots were treated with the herbicide trifluralin (0.8 l/360 l water) and fertilized (16-20-0-14 and 11-51-0-2 at 112 kg ha^{-1}). Prior to seeding, seeds were treated with a formulated dressing containing thiram, carbathiin and lindane (22.5 ml kg^{-1} seed). Plots were seeded in May (1996, May 27; 1997, May 15; 1998, May 14). A four-row seeder with 30-cm spacing was used to seed plots at a rate of 100 seeds per 3-m row.

Grasshoppers were provided from a laboratory reared nondiapause strain of *M. sanguinipes* (Pickford & Randell 1969). Plants were counted prior to grasshopper introduction so that each cage had 12 plants. Semicircular framed cages covered in screening material, similar to the 'D'-shaped cages designed by Pickford (1963), were placed over rows 2 and 3 for both defoliate and nondefoliate plots. In June, 12 fourth or fifth instar grasshoppers were placed into the D cages when plants were in the 3 to 5 leaf stage (1996, June 13; 1997, June 9; 1998, June 12). Twelve grasshoppers per cage corresponds to approximately 30 grasshoppers per m^2. Grasshoppers and cages for each defoliated or control pair were removed at 50% defoliation, *i.e.*, when approximately 50% of leaf material (visual estimate) had been consumed. In 1997 and 1998 the number of days between grasshopper introduction and removal was recorded. Immediately after completion of defoliation, plants were counted to determine survival and two plants were removed from each cage to quantify actual defoliation levels. Plant phenology (Harper & Berkenkamp 1975) and height were determined before plants were dried (60°C for 72 h) and weighed. Plant height and phenology were measured two, four and six weeks postdefoliation. In late August, plants were harvested and yields and 100-seed weights measured.

The study was seeded in a split- plot design [main plots– cultivars, subplots–defoliation (no defoliation or grasshopper defoliation)] and there were four blocks for each year. Replicates (n = 3) were based on years. Orthogonal contrasts were used for means separation. Statistical analyses were conducted using GLM Procedure (SYSTAT 1998).

Results

The length of time required for grasshoppers to defoliate approximately 50% of the leaf material varied among species. Mean defoliation time was 5.6 d and ranged between 3.9 d for *B. napus* cv. 'Midas' and 8.0 d for *S. alba* cv. 'Ochre'. Overall, the defoliated plants weighed 38.9% less than the controls (p = 0.0003). Plant weights after defoliation for the two *S. alba* cultivars ('AC Pennant' and 'Ochre') were significantly (p = 0.0001) greater than for other species (Table 1). Weight differences between defoliated and control plants were less for *B. rapa* (27.5% less than controls) than *B. napus* (44.8%), *S. alba* (43.1%) or *B. juncea* (40.2%).

Table 1. Mean dry weights (mg) of plants defoliated by grasshoppers and control plants; dry weight defoliation expressed as a percentage of controls.

Cultivar	Controls	Defoliated Plants	Dry Weight as % Control
S. alba			
Ochre	585	335	57.4
AC Pennant	359	203	56.5
B. juncea			
J92-223	108	83	77.3
AC Vulcan	245	104	42.3
B. napus			
Midas	80	48	60.6
AC Excel	129	64	49.9
B. rapa			
AC Parkland	208	198	95.6
Echo	336	166	49.4

Due to uneven defoliation, there were instances of plant mortality in the treated cages and survival for control plants (mean = 10 plants per cage) was significantly greater (p = 0.0006) than for defoliated plants (mean = 8.9). Grasshoppers caused higher mortality in 'AC Excel' (22.8%) than the other cultivars.

The impact of grasshopper damage on plant development was examined across all cultivars, between cultivars and between species. Overall plant development, two weeks postdefoliation, ranged from the late true leaf stage to very early flowering. Overall, phenology of the defoliated plants lagged 5.6% behind controls (p = 0.0058). However, by four weeks postdefoliation, overall phenology between defoliated and control plants was not significantly different (p = 0.3947). Phenologies were also significantly different between cul-

Table 2. Mean cultivar yields (gm) and 100-seed weights (mg) for controls and plants defoliated by grasshoppers in field cages (1996-1998).

	Yield (gm)		%	100 seed weight (mg)		%
Cultivar	Controls	Defoliated	Reduction	Controls	Defoliated	Reduction
AC Vulcan	87.6	70.4	19.6	253.2	251.2	0.8
Echo	61.7	48.8	20.9	203.6	214.3	5.3
Midas	67.6	52.2	22.8	280.6	278.4	0.8
J92-223	84.9	64.7	23.8	259.8	242.6	6.6
AC Parkland	52.2	38.9	25.5	214.6	206.9	3.6
Ochre	85.0	60.3	29.1	565.7	535.2	5.4
AC Pennant	90.4	62.4	31.0	558.3	544.3	2.5
AC Excel	75.2	39.4	47.6	264.0	256.5	2.8

Table 3. Mean overall cultivar yields (gm) in field cages, based on combined yields of damaged and control plants.

Cultivar	Mean Yield (gm)
B. napus	
AC Excel	57.3
Midas	59.9
B. rapa	
AC Parkland	45.6
Echo	55.2
S. alba	
AC Pennant	76.4
Ochre	72.6
B. juncea	
AC Vulcan	79.0
J92-223	74.8

tivars (p = 0.0006) at two weeks postdefoliation and at four weeks postdefoliation (p = 0.0001). Plant development of *B. napus* cultivars ('AC Excel' and 'Midas') was slower after grasshopper defoliation than in the other species.

Overall yield of the defoliated plants was significantly less than controls (p = 0.0001) with a mean reduction of 27.8%. Seed weights were significantly less than controls (p = 0.0300). Yield loss was greatest for 'AC Excel' (47.6%) and least for 'AC Vulcan' (19.6%) (Table 2). At the species level, yield loss was greater for *B. napus* (35.2%) (p = 0.0001) than for other species (*S. alba* = 30.0%, *B. rapa* = 23.2% and *B. juncea* = 21.7%).

Overall yields (yields of control and defoliated plants combined for each cultivar) showed that 'AC Vulcan', 'AC Pennant', 'J92-223' and 'Ochre' performed significantly better than the remaining cultivars (p = 0.0001) (Table 3). At the species level, *B. juncea* and *S. alba* yields were not significantly different from each other (p = 0.4111).

The data show that defoliation results in yield loss. However, there was no clear relationship between the level of defoliation and yield (Fig. 1). When yields and dry weights of defoliated plants are expressed as a percent of respective controls, yields of defoliated plants varied less than dry weights. Initial dry weights of defoliated plants ranged 49.4% to 95.6% of controls, while yields of defoliated plants ranged 52.4 to 80.4% of controls. In some cases, the relationship between level of defoliation (dry weight) and yield was close to 1:1; mean dry weights of defoliated plants of 'AC Excel' (*B. napus*) were 49.9% of controls and mean yield for defoliated plants was 52.0% of controls. In other cases, relatively less defoliation (dry weight) was associated with greater yield loss; mean dry weight of defoliated plants of 'AC Parkland' (*B. rapa*) was 95.6% of controls and mean yield of defoliated plants was 74.5% that of controls. At the other extreme, mean dry weight of defoliated plants of 'AC Vulcan' (*B. juncea*) was 42.3% of controls; however, mean yield was 80.4% of controls.

Discussion

Plant size at the time of grasshopper defoliation influenced the length of time to reach desired defoliation, level of plant mortality and subsequent yield loss. Although the length of time required for grasshoppers to remove approximately 50% of leaf material did not differ among cultivars, the type of plant damage appeared to

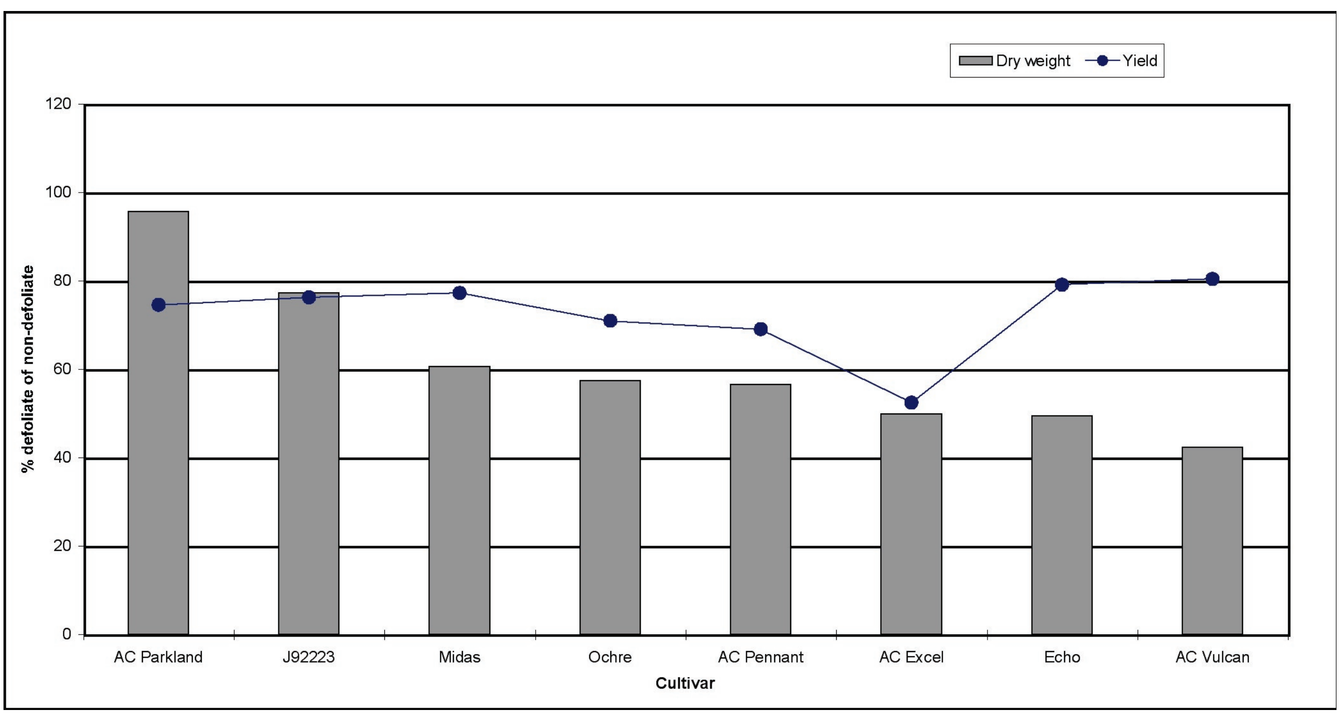

Fig. 1. Relationship between plant dry weight after defoliation and yield. Values are expressed as percent defoliated of nondefoliated (control) plants.

differ. Large plants tended to have feeding damage on leaves, while grasshopper feeding on small plants often resulted in 'clipping' of entire leaf petioles or entire shoots.

Large plants can be expected to take longer to defoliate than small plants. The fact that *S. alba* cultivars took 25% longer than the other species to reach the planned level of defoliation in this study may be an indication of feeding deterrence, or it may simply reflect plant vigor. The cultivars of *S. alba* had relatively larger shoots (main and axial) than the other entries, so that grasshopper feeding rarely resulted in complete severing of the main or axial shoots.

Grasshopper damage at the 3 to 5 leaf stage had minimal effect on delaying plant development. This suggests that if grasshopper populations are controlled at, or prior to, the 3 to 5 leaf stage, there should be no delay in plant maturity and so no delay in harvest.

The study indicates that while grasshopper feeding results in yield losses, mustard species *(B. juncea* and *S. alba*) have greater yields than the canola species (*B. napus* and *B. rapa*), regardless of defoliation. *B. juncea* is a relatively high-yielding species (Woods *et al.* 1991) that appears to be able to recover well from grasshopper defoliation. Of the two canola species, yield losses were significantly greater for *B. napus* than for *B. rapa*. This yield loss difference, however, may be partially offset in practice by the fact that *B. napus* cultivars typically yield more than *B. rapa* cultivars (Potts *et al*. 1999).

Based on comparative performance of canola and mustard in the Prairie Ecozone, yield of *B. juncea* cultivars is estimated at approximately 2300 kg ha^{-1} (depending on seed oil profile) while that of *B. napus* and *B. rapa* are 2000 and 1900 kg ha^{-1}, respectively (Rakow *et al*. 1995, Woods *et al*. 1991). In these studies, the equivalent mean yields of the controls were 2368, 2329, 1928 and 1538 kg ha^{-1} for *S. alba*, *B. juncea*, *B. napus* and *B. rapa*, respectively. Yields of these same crops when damaged by grasshoppers at the 2 to 4 leaf stage resulted in equivalent mean yields of 1658, 1825, 1237 and 1185 kg ha^{-1} for *S. alba*, *B. juncea*, *B. napus* and *B. rapa*, respectively. Oilseed production costs vary for the major ecoregions within the Prairie Ecozone. The yields required to break even from an economic perspective for direct-seeded oilseed crops are estimated at 1540, 1400 and 960 kg ha^{-1} for the Aspen Parkland, Moist Mixed Grassland and Mixed Grassland ecoregions, respectively (Anonymous 2000). Our results suggest that *S. alba*, *B. juncea* and *B. napus* can be grown profitably in most ecoregions in the absence of grasshoppers; however, grasshopper damage can very quickly erode net returns.

The costs for chemical control of grasshoppers are approximately Can$13 per ha (Olfert & Slinkard 1999). At a commodity price of Can$290 per tonne for mustard or canola, producers could anticipate absorbing crop losses of about 45 kg ha^{-1} before it would be economical to control grasshoppers. In this study, approximately 50% defoliation by grasshoppers at the 2 to 4 leaf stage caused yield losses which averaged 710, 504, 691 and 353 kg ha^{-1} for *S. alba*, *B. juncea*, *B. napus* and *B. rapa*, respectively.

In the context of economic and environmental concerns, the role of host plants in managing grasshopper populations also needs to be addressed (Olfert 2000). Effective suppression of grasshopper populations would reduce the overall need for insecticides, an approach that is supportive of the concept of managing grasshopper outbreaks without risking environmental disaster. Further research is ongoing to assess the impact of these food plants on the biotic potential of grasshopper populations.

Conclusions

Because the two mustard species, *S. alba* and *B. juncea*, are known to be more heat and drought tolerant, and because they produce greater yields than the canola species (*B. napus* and *B. rapa*) regardless of defoliation, they appear to be better suited for growing in areas of Saskatchewan that commonly experience grasshopper infestations. Early season grasshopper damage, 50% defoliation at the 2 to 4 leaf stage, can cause yield loss in the range of 353 to 710 kg ha^{-1} under growing conditions typical for the Canadian Prairie Ecozone. This level of damage can occur in less than one week with grasshopper populations of 30 per m^2 if control measures are not implemented.

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