Feeding and performance of Colorado potato beetle, *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae), reared on nightshade and potato

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ABSTRACT

Larval feeding rates, growth rates of immatures, and adult fecundities were measured for Colorado potato beetle fed hairy nightshade (*Solanum sarrachoides*) or potato (*Solanum tuberosum*). Hairy nightshade is an important economic weed in local agriculture. The larvae consumed more dry weight of potato foliage than nightshade. Developmental rate was higher for larvae fed potato than for those fed nightshade. Mortality was similar on the two hosts. Pupae and adults obtained from larvae reared on nightshade were significantly heavier than those from larvae reared on potato. There were no significant effects of the rearing host on adult female longevity. Fecundity, however, was higher for beetles fed on nightshade than those fed on potatoes. We conclude that hairy nightshade is an important alternative and acceptable host plant for the Colorado potato beetle.

Key words: Hairy nightshade, potato, development, foliage consumption, survival, adult longevity, fecundity

INTRODUCTION

Colorado potato beetle, *Leptinotarsa decemlineata* (Say) has adapted to different local host plants, depending upon geographic location (Harrison 1987, Hsiao 1985). Hairy nightshade, *Solanum sarrachoides* Sendt., for example, serves as an alternative host of the pest in Colorado (Horton & Capinera 1990), Utah (Hsiao, personal communication) and Washington (Brown *et al.* 1980). This weed species, a native of South America, is locally abundant in potato (*Solanum tuberosum* L.) growing regions in the Pacific Northwest (Callihan *et al.* 1990). In late season, large numbers of beetles were seen feeding and ovipositing on nightshade plants, to the extent that beetle densities were much higher on nightshade than on potato (Xu & Long, unpublished data). Feeding and performance of the beetle has not been well documented with the beetle population in Washington. This study had two objectives: first, to measure foliage consumption and survival of larval stages, and longevity and fecundity of the adult beetle fed either nightshade or potato foliage; second, to determine whether the beetle was preferably adapted to the source host (host species from which the egg mass was collected) (Horton & Capinera 1990).

MATERIALS AND METHODS

Egg masses from first generation beetles were collected from nightshade and potato plants on 9 July, 1993 at the USDA Field Station, 8 miles east of Moxee, Washington. Eggs were brought to the laboratory and kept in an incubator until they had hatched (27 ± 1 °C, 16L:8D photoperiod)

Potatoes, (var. Russet Burbank) were planted in 3-litre plastic flower pots using standard potting soil (Sun Gro Horticulture Inc., Puyallup, WA). Hairy nightshade, *S. sarrachoides*, was germinated from seed and transplanted into pots as seedlings, using the same brand of potting soil. Plants were grown in the laboratory under a pressurized sodium vapor grow light. Both host species were regularly watered and were fertilized weekly with "Schultz-Instant" Liquid Plant Food (Schultz Co.).

Five newly-hatched larvae were randomly selected from each egg mass. Larvae were individually transferred to a small plastic petri dishes (5.5 cm × 1.5 cm), with one larva per dish. Each dish contained one to four leaf disks (2 cm diameter) from the same host species from which the egg mass had been obtained. The number of leaf disks that were provided depended upon larva size. A piece of wet cotton roll was placed in each dish to maintain humidity. Dishes and larvae were placed in an incubator at a constant temperature of 27±1°C and photoperiod of 16L:8D. Observations of the larval development and survival were at 24 hr intervals. Larval instars were determined by the presence of exuvium. A total of 105 larvae from each host plant were used.

Foliage consumption by each instar was estimated using a leaf disk technique we developed. Disks were cut from leaves using a cork-borer of 2 cm diameter. One to four disks per dish were provided, and replaced daily. For measuring the leaf area consumed, several circles of the same diameter as the disks were drawn on grid paper (2.5 mm). Disks which had been fed on by larvae were placed on the circles, and the consumed areas were estimated by counting exposed square units. The number of square units were then converted to square centimeters. We found the leaf disk technique to be reliable. No significant differences in development or weight of pupae and adults were found between disk and whole plant studies, as long as enough leaf disks were provided for the beetles (Xu & Long, unpublished data).

Since potato leaves are visually thicker than nightshade leaves, there might be differences in foliage weight between the two hosts with the same leaf areas. The difference was determined by measuring the dry weights of randomly selected leaf disks of both hosts. The disks were dried in an oven at 55 °C for 48 hours before dry weights were recorded. Different quantities of foliage were also clipped from both hosts. Leaf area of the foliage was measured. Dry weight was also determined as noted above. The relationship between leaf area and dry weight was estimated using linear regression, in which dry weight (mg) was the dependent variable and leaf area (cm^2) was the independent variable. Foliage consumption was then expressed in terms of both leaf area and dry weight.

When the mature larvae stopped feeding (prepupae) they were transferred to individual rearing cups (38 ml) containing soil collected from a potato field. The cups were kept in the same incubators as those used for larval development, and were monitored daily for pupation of beetles. The pupae were checked daily until the emergence of adults. Newly emerged adults were sexed. Three to five beetles of each sex from the two host species were then randomly selected and transferred to a cage (30×30×60 cm^3) to monitor adult longevity and fecundity. A pot of nightshade or potato with young shoots was provided. Five cages were used for each host. A total of 25 females was used for the nightshade test, and 19 females for the potato test. The cages were kept at room temperature (21±1°C)with a photoperiod of 16:8 (L:D). Foliage was replaced every other day. Egg masses on plants were counted and removed daily; and the number of eggs per egg mass was also recorded. The production of eggs was calculated daily using total number of eggs on a plant divided by the number of females in that cage. Survival of adults was recorded every day until the beetles died.

As described above, all beetles in earlier studies were fed only the source host, that is, the host species from which the egg mass was obtained. But we also determined whether beetles were most adapted to their source host, using cross-host plant tests (Horton & Capinera 1990). Forty larvae newly hatched from eggs obtained on nightshade plants were randomly selected. Twenty of the forty larvae were provided with leaf disks of nightshade, and the other 20 with leaf disks of potato. Another 40 larvae hatched from eggs collected on potato plants were also used, with half of them fed nightshade and the other half fed potato. The larvae were maintained in the manner as described above. Development and survival were monitored daily until adult emergence. Pupae were sexed using the characters described by Pelletier (1993), and the weight of each pupa was recorded. Newly emerged adults were also sexed and weighed.

Data for larval feeding, adult longevity and fecundity were compared between host species using *t* - tests. Data for larval and pupal survival on the two hosts were analyzed using chi - square test. A two - way factorial (source host x feeding host) analysis of variance (ANOVA with completely randomized design) was done for data obtained from the cross - host experiments, testing for effects of source host (host from which eggs were obtained), feeding host (host for larval feeding) and their interaction. Student-Newman-Keuls tests were conducted where appropriate. (SAS Institute 1988, 1990).

RESULTS

Larval Feeding. Most foliage consumption took place in the late larval stages (Table 1). For both hosts, about 70% of the leaf area was consumed by the fourth instars, about 20% by the third instars and less than 10% by the first and second instars. A *t* - test indicated a significant difference between the two hosts in foliage consumption (cm^2) for the entire larval period, (p = 0.0017). Larvae consumed more potato than nightshade foliage for completion of their development. However, the *t* - test failed to show significant differences between the two hosts in larval feeding for the first, second and fourth instars. The difference was significant for the third instar, which may have contributed to the significant difference in total larval feeding (Table 1).

Table 1.
Average foliage consumption (per stage) by larval Colorado potato beetles[1]

	Leaf area [cm^2(SE)]		Dry weight [mg(SE)]	
Larval stage	Nightshade	Potato	Nightshade	Potato
1st instar	0.48(0.02)a	0.51(0.02)a	0.79(0.03)a	1.66(0.08)b
2nd instar	1.49(0.09)a	1.69(0.11)a	2.43(0.15)a	5.51(0.36)b
3rd instar	5.17(0.22)a	6.39(0.25)b	8.42(0.36)a	20.82(0.83)b
4th instar	19.05(0.38)a	19.30(0.41)a	31.07(0.63)a	62.95(1.33)b
Entire larval stage	26.19(0.35)a	27.88(0.40)b	42.71(0.56)a	90.94(1.30)b

[1] 85 individuals developed on nightshade foliage and 90 on potato foliage. Means followed by different letters within the same row are significantly different, *t* - test (p < 0.05).

Leaf disks of potato were thicker than those of hairy nightshade, and consequently, dry weight differed between the two hosts. On average, dried potato leaf disks weighed 10.22 mg (SE = 0.18, n = 20); dried nightshade leaf disks weighed 5.23 (SE = 0.12, n = 20). A linear regression model was fitted to the relationship of dry weight (Y) to leaf area (X):

For nightshade foliage: $Y = 1.089 + 1.602 * X$ ($R^2 = 0.997$, n = 22);

For potato foliage: $Y = - 0.321 + 3.277 * X$ ($R^2 = 0.999$, n = 20).

Leaf area consumption was then transformed to dry weight using these models. As indicated by *t* - test, on a dry weight basis, beetles consumed significantly more potato than nightshade foliage (Table 1).

Survival. Larval survival of the beetle was similar on the two hosts ($p > 0.05$). Little difference in pupal survival was found between the two hosts ($p > 0.05$, Table 2). Sixty-nine adults emerged from 105 individuals fed on potato foliage, and sixty-five from same number of individuals fed on nightshade foliage.

Table 2.

Survival (%±SE) of total larval and pupal Colorado potato beetles

Developmental stage	Nightshade	Potato	*p* - value
1st instar	93.33±2.44	99.05±0.95	0.9739
2nd instar	93.88±2.42	98.05±1.36	0.9810
3rd instar	95.65±2.12	95.10±2.14	0.9975
4th instar	86.36±3.66	83.51±3.77	0.9862
pupa	85.53±4.04	85.19±3.95	0.9984

Adult longevity. Adult beetles survived for about two months, although there was a large variation among individuals. On nightshade foliage, the range of longevity varied from 9 to 65 days for females, and 24 to 61 days for males. On potato foliage, the range was 13 - 57 days for females, and 12 - 57 days for males. As shown in Table 3, the average longevity of females was similar for the two hosts ($p = 0.8198$); the average longevity of males was significantly different between the two hosts ($p = 0.0138$).

Table 3.

Adult longevity in days[1]

		Nightshade		Potato
	N	Mean±SE	N	Mean±SE
Female	25	37.76±2.80a	19	38.82±3.84a
Male	23	41.35±2.20a	17	31.94±3.02b

[1] Means followed by different letters in the same row are significantly different, *t* -test ($p < 0.05$).

Fecundity. Egg mass per female ranged from 4 - 43 on nightshade foliage, and 7 - 32 on potato foliage. Females that developed on nightshade showed higher fecundity than those on potatoes; those fed on nightshade foliage laid about 6 more egg masses per female than those fed on potato foliage ($p = 0.0401$). The number of eggs per female was thus higher for beetles on nightshade than those on potato ($p = 0.0221$). A t - test failed to show a significant difference in number of eggs per egg mass between females fed on the different host plants ($p = 0.3041$) (Table 4).

Table 4.
Fecundity of Colorado Potato Beetles[1]

	Nightshade		Potato	
	N	Mean±SE	N	Mean±SE
Egg masses/female	25	25.44±2.67a	19	18.15±3.06b
Eggs/female	25	495.36±53.60a	19	395.42±61.69b
Eggs/egg mass	636	19.39±0.72a	345	20.51±0.70a

[1] Means followed by different letters in the same row are significantly different, t -test ($p < 0.05$).

Cross - host test. Larval development time (days) was not affected by source host ($p = 0.1652$), whereas the effect of feeding host was highly significant ($p = 0.0001$). The interaction between source host and feeding host was not significant ($p = 0.0805$), indicating that the effect of feeding host on larval development was independent of source host. Larvae that fed on potato foliage developed faster than those fed on nightshade foliage (Table 5).

Table 5.
Effects of source host and feeding host on larval development time (days±SE), pupal weight and adult weight (mg±SE) of Colorado potato beetles[1]

Source Host	Nightshade		Potato	
Feeding Host	Nightshade	Potato	Nightshade	Potato
Development time (58)[2]	15.49±0.19a	14.26±0.26b	15.94±1.67a	13.87±0.22b
Female pupa (33)	176.28±2.95a	121.65±3.98b	162.76±2.60a	126.20±3.66b
Male pupa (31)	143.90±3.75a	104.75±1.75b	142.88±4.44a	118.66±2.88b
Female adult (29)	138.06±3.41a	93.57±8.84b	138.15±4.13a	107.13±3.96b
Male adult (28)	121.30±1.73a	85.66±3.09b	117.48±3.77a	101.04±3.17ab

[1] Means followed by different letters within the same row are significantly different, Student-Newman-Keuls test ($p < 0.01$).
[2] Degree of freedom from ANOVA.

The effects of feeding host on pupal and adult weight were also highly significant ($p = 0.0001$ for pupal female and male, $p = 0.0006$ for adult male and $p = 0.0005$ for adult female, respectively). Pupae and adults from larvae that were fed nightshade foliage were significantly heavier than those from larvae fed potato foliage. Pupal females were heavier than males, so were adult females than males. Adults were lighter than pupae (Table 5). ANOVA failed to demonstrate significant source host effects or a significant interaction of source host with feeding host ($p > 0.05$).

Percent survival of larvae was similar for both source hosts and for both feeding hosts. For nightshade as source host, survival of post-hatching immatures (first instar through pupa) was 70% when nightshade foliage was provided as a feeding host, and 80% when potato foliage as a feeding host. Similarly, for potato as source host, survival was 80% on nightshade foliage, and 65% on potato foliage.

DISCUSSION

Hairy nightshade is an important host plant of the Colorado potato beetle in Washington and other areas (Horton & Capinera 1990). This weed is locally abundant in potato growing regions in the Pacific northwest (Callihan *et al.* 1990), and serves as an alternative food source for the beetle (Brown *et al.* 1980). Adults readily deposited eggs on hairy nightshade (Table 4).

The performance of Colorado potato beetles on the two feeding hosts was independent of source host, indicating that the beetle is not adapted to a particular source host. Movements of beetles between the two hosts were found in Washington, so the lack of specificity on the source host is not surprising. The first summer generation of the beetle develops primarily on potato, because the weed seeds generally do not germinate until after growth of the potatoes. However, adults of this generation readily move off potato to nightshade for oviposition (Xu & Long, unpublished data). Thus, a given female may deposit eggs on both host species. Population densities of the second summer generation were much higher on this weed species than on potato (Xu & Long, unpublished data). We conclude that populations of the beetle have adapted to the potato-nightshade plant system in the Pacific Northwest, especially in Washington.

Developmental rates of the beetle depend upon the host species (Brown *et al.* 1980, Melville 1985), but variation occurs between geographic populations. We found that larvae fed on nightshade foliage developed more slowly than those fed on potato foliage (Table 5). In Colorado, however, larval growth rates were significantly faster on hairy nightshade than on potato, both early and late in the season (Horton *et al.* 1988, Horton & Capinera 1990).

Survival of the beetle differs among different host plants (Hare & Kennedy 1986). Wild species are less acceptable host plants for the Colorado potato beetle (Melville 1985, Neal *et al.* 1991). We found that there were no significant differences in larval or pupal mortality between the two hosts (Table 2).

Fecundity of the beetles is also affected by different host plants (Brown *et al.* 1980). The beetle may prefer one host plant for oviposition over another, and higher fecundity can be seen on wild species than on the cultivated potato (Jansson *et al.* 1989). Based on the field observations made in 1992 - 1994 in central Washington, we found much higher egg mass densities on hairy nightshade foliage than on potato in mid - and late - season. The free-choice tests conducted in the laboratory indicated that adults of the first summer generation preferred nightshade to potato foliage for oviposition (unpublished data). Females fed on nightshade foliage deposited 6 more egg masses than those fed on potato foliage (Table 4). In paired preference tests conducted by Horton and Capinera (1990), females deposited 92% of egg masses on the hairy nightshade.

Hairy nightshade plays a very important role in the life history and population dynamics of the Colorado potato beetle. The importance of this species as a good alternative host plant, and the beetle's movements between the nightshade and potato should be considered in monitoring the development of insecticide resistance and integrated management of the beetle.

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