CROP PROTECTION

Consumption Rates and Performance of *Erinnyis ello* L. on Four Cassava Varieties

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Taxas de Consumo e Desempenho de *Erinnyis ello* L. em Quatro Variedades de Mandioca

RESUMO - O consumo foliar de mandioca (*Manihot esculenta* Crantz) e a caracterização da injúria potencial por *Erinnyis ello L.* foram determinados em quatro variedades de mandioca. Lagartas de primeiro ínstar foram criadas individualmente em folhas de quatro variedades de mandioca. Foi usado o delineamento experimental de blocos ao acaso com nove repetições. Folhas frescas com áreas previamente determinadas foram fornecidas às larvas diariamente. O consumo foliar em cada ínstar e o peso das lagartas e pupas foram registrados. Não houve diferença significativa no consumo foliar nas quatro variedades (P=0,82). O total de área foliar consumida (cm^2) para as variedades testadas foi: 1030,5 (Fio de Ouro), 971,5 (Aipim Bravo), 968,6 (Urubu), 956,1 (Jaburu), sendo de 981,7 o consumo médio das quatro variedades. Aproximadamente 94% do consumo ocorreu durante os dois últimos ínstares. Variedades não afetaram o desenvolvimento larval (P=0,96). Os pesos médios de lagartas (g) em cada variedade foram: 4,9 (Jaburu), 4,8 (Fio de Ouro), 4,7 (Urubu), 4,6 (Aipim Bravo) e 4,8 (média das quatro variedades). Dois modelos, um relacionando a área foliar consumida e desenvolvimento larval ($y = ab^{x}c^{x^2}$) e outro do crescimento larval ($y=5/1+e^{a+bx}$), foram estabelecidos. Os dados obtidos indicam que as variedades testadas neste estudo foram nutricionalmente semelhantes para o desenvolvimento de *E. ello*. Como o consumo foliar de *E. ello* foi semelhante para todas as variedades, a mesma taxa de consumo pode ser usada para o cálculo dos níveis de dano econômico para manejar *E. ello* nessas variedades.

PALAVRAS CHAVE: Insecta, mandarová-da-mandioca, consumo foliar.

ABSTRACT - A laboratory experiment to determine the consumption rates of cassava (*Manihot esculenta* Crantz) and characterize the injury potential by *Erinnyis ello* L. was conducted. First instar larvae were individually reared on excised cassava leaves of four varieties. A randomized block design with nine replications was used. Fresh leaves were provided to the larvae daily. Leaf area was determined for each leaf before the leaves were provided to the larvae. Foliage consumption per instar, developmental time and weight of larvae and pupae were recorded. There were no significant differences in the larval consumption on the four varieties (P=0.82). Total leaf area consumption (square cm) for the varieties were: 1030.5 (Fio de Ouro), 971.5 (Aipim Bravo), 968.6 (Urubu), 956.1 (Jaburu) and across varieties was 981.6. About 94% of the feeding occurred during the last two larval instars. Varieties also had no effect on larval development (P=0.96). Mean larval weight (g) were: 4.9 (Jaburu), 4.8 (Fio de Ouro), 4.7 (Urubu), 4.6 (Aipim Bravo), and across varieties was 4.8. Two models, one relating larval leaf-feeding and larval development ($y = ab^{x}c^{x^2}$) and another for larval growing ($y=5/1+e^{a+bx}$), were established. These data indicate that the varieties tested in this study were equally suitable for *E. ello* development. In addition, because the consumption rates of *E. ello* are the same across varieties, a single value can be used in determining economic injury levels to manage *E. ello* on these varieties.

KEY WORDS: Insect, cassava hornworm, leaf consumption.

Cassava, *Manihot esculenta* Crantz, is among the major food staples for low-income people of Latin America. In Brazil, cassava is grown in a variety of climates under a wide range of agronomic practices, often in intercropping with corn and beans. Consequently, average yields vary greatly among geographic regions and years of cultivation.

The cassava hornworm (*Erinnyis ello* L.) is a major defoliator of cassava (Belloti & van Schoonhoven

1978).Females lay eggs singly, preferentially on the upper surface of the leaves, although eggs can occasionally be found in petioles, stems, and lower surface of the leaves. First instar larvae consume the egg shell before moving to the leaf undersurface to start feeding. There are five larval instars that feed on leaves (Winder 1976). Large population can defoliate plants quickly and after having consumed all leaf tissue, larvae can feed on stem tissue and lateral buds.

Several damage-simulation studies on cassava have attempted to quantify yield loss relationships resulting from defoliation on cassava. Even though yield loss varies in these experiments, it is consistent that defoliation occurred during the latter growth stages has little effect on yield, where as at earlier stages it has greater effect on yield (Farias *et al.* 1982; Arias & Bellotti 1984; Porto & Hamers 1987a,b). Defoliation also has an effect on content of starch in roots (Farias *et al.* 1982). As a result of injury, plants have less foliage and are shorter than non-injured plants Although this insect is known to feed on cassava, it is also important pest of rubber three (*Hevea brasiliensis*) as well (Abreu *et al.* 1982). Outbreaks normally occur, in the beginning of the rainy season.

Information about the damage potential of *E. ello* to cassava is necessary before economic injury levels can be established. A laboratory experiment was conducted to determine the *E. ello* consumption rates on four cassava varieties. Additionally, the total dry matter consumed and larval development on cassava were determined. These data provide important information on the basic biology of cassava hornworm and offer a foundation for work on an IPM program for the species.

Material and Methods

An experiment was conducted between January 28 and February 17, 1998 in the laboratory at Embrapa Meio-Norte Experimental Station located near Parnaíba, PI. Cassava hornworm eggs were collected from the field, and held until hatching. First instar larvae (<3h after eclosion), from field collected eggs, were placed individually into 20 x 30 x 10 cm plastic containers and reared on excised cassava leaves of four varieties: (Aipim Bravo, Fio de Ouro, Jaburu, e Urubu) at 27ºC. Varieties, with high and low levels of cyanide, were chosen among the most commonly grown in the states of Piauí and Maranhão (Azevedo *et al.* 1998). Two sheaths of towel paper, moistened with distilled water, were placed to maintain approximately 75% RH in the container.

Leaves of the four cassava varieties were collected in the field from 10-month old cassava plants. Leaves used in the experiment were picked from the fourth node from the terminal, collected at 08:30h-10:00h, immediately placed in plastic bags, kept in a cooler and brought to the laboratory. Leaves were maintained with petiole placed in test tubes filled with water to prevent them from wilting. A randomized block design with nine replications for each variety was used. Each plastic container with a larva represented an experimental unit.

Fresh leaves were provided to larvae daily beginning from the third day of the experiment. Leaf areas were determined for each leaf using a leaf area meter (Model 3100, LI-COR, Lincoln NE, USA) before the leaves were provided to the larvae. Daily, leaves were removed from the containers and leaf areas were determined. Then, leaves were either replaced or returned to the plastic containers. Foliage consumption per instar and weight of larvae and pupae were recorded (Denver Instrument AA-250).

Total leaf tissue consumption and consumption rates per instar for each larva in each variety were determined until feeding ceased. Specific leaf weights were quantified by determining the ratios between leaf area and dry weight (mg dry wt/cm^2) of remaining tissue.

Analyses of variance (ANOVA) were conducted to determine if significant differences occurred in leaf consumption and weight of larvae fed on different varieties. Leaf consumption and larval weight also were analyzed with regression using PROC GLM procedure (SAS Institute 1990) to model leaf consumption and larval growth. Because there were no differences in leaf consumption or larval weight among cassava varieties, data were analyzed with regression combining data of all varieties. Parameter estimates were obtained after linearization of the models.

Results and Discussion

Leaf Consumption. Larvae fed in all varieties for 14 days and then pupated. Analysis of variance indicated no significant differences in leaf consumption rate by cassava hornworm on varieties tested (P=0.82) (Table 1). Total leaf area consumption (square cm) by variety was: 1030.5 ± 63.20 (Fio de Ouro), 971.5 ± 34.24 (Aipim Bravo), 968.6 ± 75.73 (Urubu), and 956.1 ± 37.30 (Jaburu). Little leaf tissue was consumed during the first three larval instars.

Combined data of all varieties shows a minimum of 3.6 ± 0.27 cm^2 was eaten by a first instar and a maximum of 823.7 ±

Table 1. Mean (± SE) leaf area (cm^2) consumed by *E. ello*, to complete each larval instar on four cassava varieties (27ºC, 75% R.H., 13 light:11 dark).

DAH[1] Instar	A. Bravo	F. Ouro	Jaburu	Urubu	Combined
2 (L_1)	3.2 ± 0.45	3.7 ± 0.59	4.3 ± 0.54	3.0 ± 0.58	3.6 ± 0.27
3 (L_2)	12.6 ± 1.93	15.8 ± 2.22	11.7 ± 2.37	13.8± 2.54)	13.4 ± 1.12
6 (L_3)	41.9 ± 5.70	37.5 ± 8.90	44.4 ± 11.22	37.8 ± 6.51	40.4 ± 4.03
8 (L_4)	90.0 ± 12.28	102.0 ± 12.84	108.0 ± 18.46	101.5 ± 11.16	100.5 ± 6.77
14 (L_5)	823.8 ± 44.28	871.5 ± 63.04	787.1 ± 14.67	812.5 ± 82.76	823.7 ± 28.88
Total	971.5 ± 34.24	1030.5 ± 63.20	956.1 ± 37.30	968.6 ± 75.73	981.6 ± 26.95

[1]Days after egg hatch

28.88 cm^2 was eaten by fifth instar. Consumption by fourth and fifth instars together constituted approximately 94% of the total leaf area consumed by all instars and occurred within eight days. Total leaf area consumption (average for all varieties combined) was 981.64 ± 26.95 cm^2. Cassava hornworm consumption pattern was similar to those reported for other caterpilars (Hammond *et al.* 1979, Shields *et al.* 1985, Trichilo & Mark 1989, Kidd & Orr 2001). These results agree with observations by other researchers that fourth and fifth instars are of critical economic importance.

The mean cumulative consumption of dry leaf tissue (mg/larva) for each variety were: 3128.1 ± 110.26 (Aipim Bravo), 3181.6 ± 195.15 (Fio de Ouro), 2916.0 ± 113.76 (Jaburu) and 2857.3 ± 223.39 (Urubu) (Table 2). There were no significant differences in the larval consumption in dry weight on the four varieties (P=0.53), because the surface areas and dry weight ratios were similar for all varieties. Daily consumption by larvae increased with advancing instar. Determination of specific weight is important for compensate for differences in leaf tissue thickness among varieties, when comparing the amount of leaf area that larvae will consume (Hammond *et al.* 1979, Kidd & Orr 2001).

Combined data of leaf area consumption (LAC) by cassava hornworm (Table 1) were regressed on larval developmental time (days after egg hatch). An exponential model was chosen after linearization of the data using logarithm transformation:

$$y = ab^{x}c^{x^2} \quad (R^2 = 0.994), \text{ where,} \qquad [1]$$

y= cumulative leaf consumption, x= days after eggs hatch and a=0.8795, b=2.2155, and c=0.9701 are the estimates.

The pattern of consumption by larva was similar for both dry weight and leaf area. Consumption was negligible for first and second instar as shown in the model (Fig. 1). The mean consumption increased exponentially and was related to larval instar.

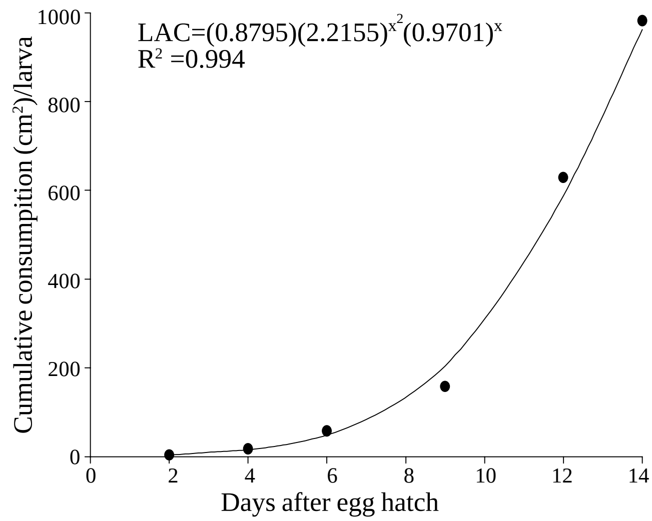

Figure 1. Leaf consumption model expressing relationship between *E. ello* development and larval feeding (27°C, 75% R.H., 13 light: 11 dark).

Larval Development. The larval stage in this experiment lasted 14 days. Similar to results with leaf area and dry tissue weight consumption, varieties also had no effect on total larval fresh weight (P=0.96). The mean weight (mg) for older fifth-larval instar were: 4.93 ± 0.350 (Jaburu), 4.83 ± 0.230 (Fio de Ouro), 4.74 ± 0.178 (Urubu), and 4.61 ± 0.242 (Aipim Bravo) (Table 3). The mean weight of larvae (mg/instar), obtained on four varieties were combined and

Table 2. Mean (± SE) leaf dry weight (mg) consumed by *E. ello* on four cassava varieties (27°C, and 75% R.H., 13 light:11 dark).

DAH[1] Instar	A. Bravo	F. Ouro	Jaburu	Urubu	Combined
2 (L_1)	10.2 ± 1.46	11.4 ± 1.83	13.2 ± 1.65	8.9 ± 1.59	10.9 ± 0.83
3 (L_2)	40.6 ± 6.22	48.8 ± 6.85	35.8 ± 7.22	40.7 ± 7.49	52.4 ± 3.83
6 (L_3)	134.8 ± 18.35	115.6 ± 27.49	135.3 ± 34.22	111.5 ± 19.21	176.7 ± 15.47
8 (L_4)	289.9 ± 39.53	315.0 ± 39.63	330.9 ± 56.31	299.1 ± 32.92	485.6 ± 32.49
14(L_5)	2652.5 ± 142.58	2690.7 ± 194.66	2400.8 ± 112.07	2396.8 ± 244.15	2535.2 ± 89.38
Total	3128.1 ± 110.26	3181.6 ± 195.15	2916.0 ± 113.76	2857.3 ± 223.39	3020.8 ± 83.66

[1]Days after egg hatch

Table 3. Mean (± SE) weight (mg) of larvae and pupae of *E. ello* reared on four cassava varieties (27°C, 75% R.H., 13 light:11 dark).

DAH[1]/Instar	A. Bravo	F. Ouro	Jaburu	Urubu	Combined
2 (L_1)	0.03 ± 0.004	0.03 ± 0.005	0.03 ± 0.005	0.03 ± 0.005	0.03 ± 0.002
3 (L_2)	0.13 ± 0.019	0.14 ± 0.025	0.12 ± 0.024	0.14 ± 0.025	0.13 ± 0.011
6 (L_3)	0.45 ± 0.072	0.50 ± 0.111	0.53 ± 0.118	0.51 ± 0.107	0.50 ± 0.050
8 (L_4)	1.307 ± 0.146	1.45 ± 0.217	1.50 ± 0.290	1.59 ± 0.243	1.46 ± 0.111
14 (L_5)	4.61 ± 0.242	4.83 ± 0.230	4.93 ± 0.350	4.74 ± 0.178	4.78 ± 0.125
Pupa	3.8 ± 0.131	3.91 ± 0.098	4.04 ± 0.127	3.84 ± 0.216	3.90 ± 0.073

[1]Days after egg hatch

adjusted to a growth curve logistic:

$$y=5/1+e^{a+bx} \quad (R^2=0.999), \text{ where,} \qquad [2]$$

y= cumulative larval fresh weight, x= days after eggs hatch and a=6.389, b=-0.6803, and e is the base of neperian logarithm.

During the first six days the growth rate was small and larvae showed a small change in fresh weight for the first two instars. From the fourth instar, an increase in weight occurred continuously until older fifth instar when fresh weight increases ceased and larvae pupated (Fig. 2). The largest increase in growth rate occurred between 8 and 12 days. In general, fourth and fifth instars accounted for approximately 86.2% of the overall weight gain. Maximum gain occurred in the fourth instar.

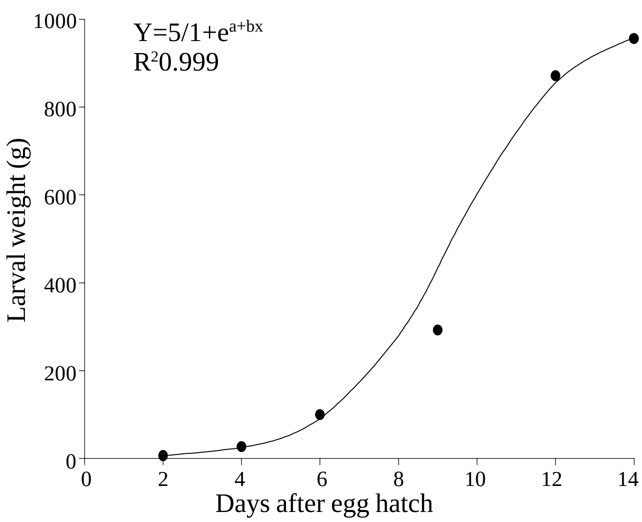

Figure 2. Larval growth model expressing the relationship between *E. ello* weight gain and developmental time (27°C, 75% R.H., 13 light: 11 dark).

Lepidopteran larvae feed on leaves with different nutrition quality, variable levels of non-nutritive fibre and allelochemicals. Consequently, several species increase consumption on foods with reduced nutrient levels. The increase in food consumption may result in an alteration in growth rate of some caterpilars (Slansky & Wheeler 1989, 1991).The absence of significant differences in leaf consumption and larval development across varieties is an indication that varieties tested in this study have similar suitability for *E. ello*. The fact that the levels of cyanide in the leaves are variable across varieties (Urubu: high; Aipim Bravo, Jaburu, and Fio de Ouro: low) (Azevedo *et al.* 1998), suggests that cyanide content does not influence *E. ello* larval development.

Our data indicate that the varieties tested in this study had similar impact on the adaptation and biology of *E. ello* which indicate that the same parameter will determine the population growth on these varieties. The high correlation between dry leaf weight and leaf area consumption supports this conclusion. Also, it is clear that the first three larval instars cause very little injury. In addition, because there were no significant differences in the consumption rates of *E. ello*, a single value can be used to determine the economic injury levels to manage *E. ello* on these varieties.

The prediction of consumption rate is an important component of IPM, because leaf area consumption is essential to the determination of the economic impact of an insect defoliation (Pedigo *et al.* 1986). Also, because about 94% of the defoliation occurs in the last two larval instars, sampling young larvae will allow some days to take decision or to take another sample if results are inconclusive. Larvae are also subject to heavy natural parasitism and predation (Winder 1976) and many do not survive to the damage stages of development, thus the number of larvae causing actual damage actually may be less than the number sampled.

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