Insect Sci. Applic. Vol. 16, No.1, pp. 87–91, 1995
Printed in Kenya.

0191-9040/95 $3.00 + 0.00

IMPACT OF THE GROUNDNUT LEAFMINER, *APROAEREMA MODICELLA* (DEVENTER) (LEPIDOPTERA: GELECHIIDAE) ON GROWTH AND YIELD OF TWO GROUNDNUT CULTIVARS

T.G. SHANOWER*[1], A.P. GUTIERREZ[2] and J.A. WIGHTMAN[1]
[1]Crop Protection Division, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India;
[2]Division of Biological Control, University of California, Berkeley, 1050 San Pablo Ave., Albany, CA 94706, USA

(*Accepted* 26 *June* 1995)

Abstract—The impact of larval defoliation by *Aproaerema modicella* (Deventer) on the growth, development and yield of two groundnut cultivars (Kadiri 3 and NC Ac 17090) was studied under a naturally occurring, high density infestation. Defoliation by leaf-mining larvae did not increase plant mortality in either cultivar. In both cultivars, leaf and stem production were significantly lower in untreated plots than in the treated plots. Unsprayed plants of both cultivars produced fewer flowers, pegs, and pods per plant compared to plants of the same cultivar protected with monocrotophos. Fruit growth rates, however, were marginally higher in control plots than in treated plots. Pod yields were 35 and 44% lower, and haulm yields 25 and 20% lower, in Kadiri 3 and NC Ac 17090, respectively in untreated control plots compared to plots treated with insecticide. A linear relationship between leafminer density and pod and haulm yields was observed, and differences between cultivars were not significant.

Key Words: *Aproaerema modicella*, groundnut, yield, plant growth, cultivars, south India

Résumé—Cette étude a porté sur l'impact de la défoliation par les larves de *Aproaerema modicella* (Deventer) sur la croissance, le développement et le rendement de deux cultivars d'arachide (Kadiri 3 et NC Ac 17090) dans des conditions d'infestation naturelle à densité élevée. La défoliation n'a augmenté la mortalité de plantes ni chez l'un ou l'autre de ces cultivars. Pour les deux cultivars, la production de feuilles et de tiges était sensiblement réduite dans des parcelles non-traitées par rapport aux parcelles traitées. Des plantes non-pulvérisées des deux cultivars ont produit moins de fleurs, de gynophores et de gousses par plante, par rapport aux plantes du même cultivar traitées au monocrotophos. Cependant, les taux de croissance des fruits étaient légèrement plus élevés dans des parcelles témoins que dans des parcelles traitées. Les rendements en gousses étaient de 35 et 44% moins élevés, les rendements en fanes, de 25 et 20% moins élevés, chez Kadiri 3 et NC Ac 17090 respectivement dans des parcelles témoins non-traitées par rapport au traitement insecticide. Un rapport linéaire a été constaté entre la densité d'infestation de la mineuse des feuilles et les rendements en gousses et en fanes, les différences entre cultivars n'étant pas significatives.

Mots Clés: *Aproaerema modicella*, arachide, rendement, croissance des plantes, cultivars, Inde du Sud

INTRODUCTION

Asia produces 15.2 million tonnes of groundnut (*Arachis hypogaea* L.) per year, representing 65% of the world total, with an average yield of 1148 kg/ha (FAO, 1992). India is the single largest producer, despite low yields (847 kg/ha), supplying 46% of the Asian total (FAO, 1992). The groundnut leafminer, *Aproaerema modicella* (Deventer) (Lepidoptera: Gelechiidae) is an important pest of groundnut and soybean across south Asia, and is a prime cause of

*To whom correspondence should be sent.

low groundnut yields in India (Wightman et al., 1990; Shanower et al., 1993).

Defoliators such as *A. modicella* affect groundnut by reducing the photosynthetically active leaf area. Artificial defoliation studies have shown that yield losses are greatest when defoliation of 50% or more occurs during pod formation (Enyi, 1975; Panchabhavi et al., 1986). Stem weight is particularly sensitive to defoliation, and lower stem weight has been associated with lower pod yield (Enyi, 1975; Williams, 1979; Wilkerson et al., 1984). Unfortunately, artificial defoliation studies rarely mimic the effect of insect herbivores in a realistic way.

Yield losses of up to 65% have been attributed to *A. modicella* (Sivasubramanian and Palaniswamy, 1983; Rajput et al., 1984, 1985), though little is known of its impact on groundnut growth and development. The purpose of this study was to investigate the impact of extensive and naturally occurring defoliation by the groundnut leafminer on the growth, development, and yield of two groundnut cultivars.

MATERIALS AND METHODS

Groundnut was planted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), (18°N, 78°E), Andhra Pradesh, India, during the first week of July and harvested in mid-October. A randomised complete block design with four replicates of each treatment was used. The four treatments were: two cultivars, Kadiri 3 and NC Ac 17090, under protected (insecticide) and unprotected conditions. Kadiri 3 is susceptible to the leafminer and NC Ac 17090 is considered moderately resistant. Protected plots were sprayed three times with insecticide (monocrotophos at 180 ml a.i. in 330 l water/ha).

Four rows were sown on raised beds (1.5 m), in a medium-deep Alfisol which had been planted with pearl millet the previous season. Seeds were planted 15 cm apart at a density of 210,000/ha. Plot size was 396 m^2 (11 beds x 24 m). Irrigation was supplied *ad libitum* and gypsum (67.2% $CaSO_4$) was applied at 500 kg/ha 60 days after sowing (DAS) to ensure an adequate calcium supply during pod enlargement. Daconil at 1.8 kg in 600 l water/ha) was applied to all plots for control of fungal leaf spot diseases.

Fifteen plants per plot were sampled during the first 7 weeks, and 10 plants per plot were sampled during the rest of the season for analysis of plant growth. Samples were collected weekly except during the first 3 weeks when they were collected twice weekly. The number of leaves, flowers, pegs, and mature and immature pods per plant were recorded and dry weights of plant subunits were taken 48 h after drying at 60°C. Leaf area was measured using a LI-COR (model LI-3100) photoelectric leaf area meter, and leaf area index calculated using mean leaf area per plant and plant density.

Yield data (number and dry weights of mature and total number of pods per plant and haulm yield per plant) were collected at harvest. Analysis of variance (ANOVA) was used to compare plant growth and yield variables across treatments at each sampling date. Linear regression was used to compute the rate of growth (g or number/plant/day) for each plant growth variable. Analysis of covariance (ANCOVA) was used to test differences in growth rates among treatments (Zar, 1974).

Larvae of *A. modicella* were first observed in the field 30 DAS. Weekly counts were converted to larval-days (product of larval counts and sampling interval) to compare the cumulative effect of leafminer in different treatments. Linear regression analyses were used to compare the effect of leafminer density on pod and haulm yields between cultivars (Zar, 1974). Means were separated by the Duncan's multiple range test.

RESULTS

Pest densities were highest (up to 130 larvae per plant) between 30 and 70 DAS. Cumulative larval-days varied from 15 to 1600 in the NC Ac 17090 plots and from 780 to 2700 in the Kadiri 3 plots. Differences in cumulative larval-days between sprayed and unsprayed plots were greater than twofold for both cultivars.

Plant densities in Kadiri 3 plots were significantly higher at both germination and harvest, compared to those in NC Ac 17090 plots. Differences between sprayed and unsprayed plots of the same cultivar were not significant. Plant populations in the four treatments were reduced by 23.5 to 43.3% during the season, though it did not appear that feeding by GLM caused significant plant mortality. The decrease in plant density was roughly equivalent in the two Kadiri 3 treatments, while protected plots of NC Ac 17090 lost more plants than the untreated plots.

Significantly less (ANOVA; $F_{3,9} = 24.7$; $P < 0.0005$) leaf dry matter was produced in untreated plots compared to the sprayed plots of the same cultivar (Fig. 1). Kadiri 3 plots lost more leaf biomass (33%) as a result of leafminer attack than did NC Ac 17090 plots (10%). The rate of leaf biomass accumulation was also affected by the heavy herbivore load. Unsprayed plots had lower rates of

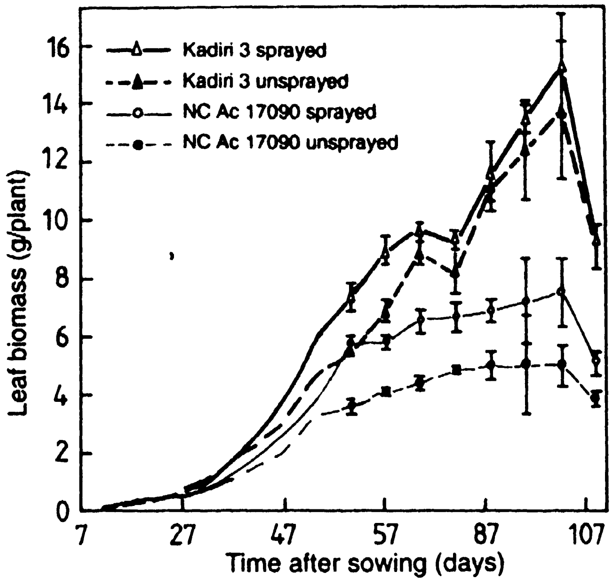

Fig. 1. Effect of defoliation by *Aproaerema modicella* larvae on the accumulation of leaf tissue in two groundnut cultivars grown under sprayed and unsprayed conditions

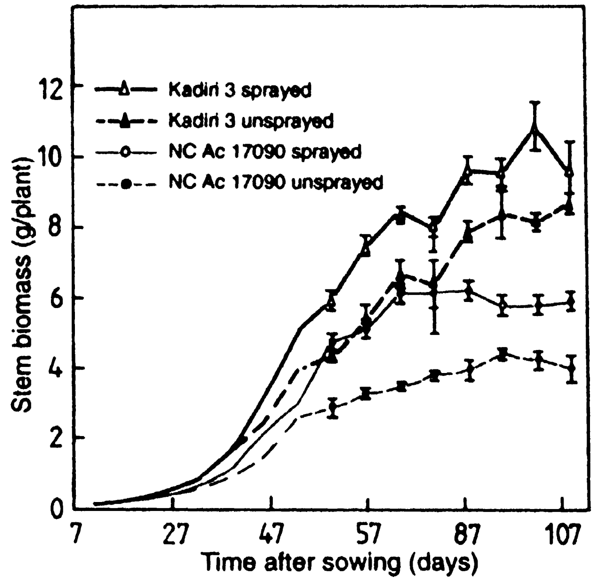

Fig. 2. Effect of defoliation by *Aproaerema modicella* larvae on the accumulation of stem tissue in two groundnut cultivars grown under sprayed and unsprayed conditions

leaf production compared to treated plots of the same cultivar (ANOVA; $F_{3,31}$ = 4.67; P ≤ 0.01). Cultivar NC Ac 17090 produced leaf biomass at a higher rate than Kadiri 3. Leaf area index was below 2.2 in all treatments and differences were not significant.

Treated plots produced significantly more stem tissue (including petioles) than unsprayed plots (ANOVA; $F_{3,9}$ = 42.87; P ≤ 0.0005). Stem biomass was 30% lower in Kadiri 3 and 20% lower in NC Ac 17090 unsprayed plots relative to the sprayed plots for each cultivar. In addition, stem biomass was 30 to 60% higher in NC Ac 17090 plots relative to Kadiri 3 plots (Fig. 2). Stem production rates were significantly lower in unsprayed plots relative to treated plots for both Kadiri 3 and NC Ac 17090 (ANCOVA; $F_{3,36}$ = 5.05; P ≤ 0.01).

More flowers were produced in insecticide-protected plots than in unsprayed plots of the same cultivar (ANOVA; $F_{3,9}$=5.92; P≤0.025). Cumulative flower production was 30% lower in Kadiri 3 and 15% lower in NC Ac 17090 in unsprayed plots compared to treated plots. Flower production rates were not significantly different between treatments.

Yields of pods and haulms were significantly lower in untreated plots of both cultivars compared to the equivalent treated plot (Table 1). Cultivar NC Ac 17090 pod yields were lower than those of Kadiri 3, though haulm yields were significantly higher. Leafminer defoliation reduced Kadiri 3 pod yields by 35% and haulm yields by 25%. Cultivar NC Ac 17090 pod yields were 44% lower and haulm yields 20% lower in untreated plots. Linear reductions in pod yields were observed in both cultivars at higher leafminer densities (Fig. 3). The slopes of the two regression lines were not significantly different (Student's *t*-test; *t* = -0.0798; *n* = 16), indicating that pod yields were reduced at similar rates as leafminer levels increase, in both cultivars. The different y-

Table 1. Effect of insecticide application on pod and haulm yields in two groundnut cultivars

Treatment	Pod [1] (g/plant)	Haulm (g/plant)
Kadiri 3 sprayed	7.4 a	13.2 c
Kadiri 3 untreated	4.8 b	9.9 d
NC Ac 17090 sprayed	4.8 b	23.8 a
NC Ac 17090 untreated	2.7 c	19.1 b

[1]Means in a column followed by the same letter are not significantly different (*P* > 0.05) according to Duncan's multiple range test.

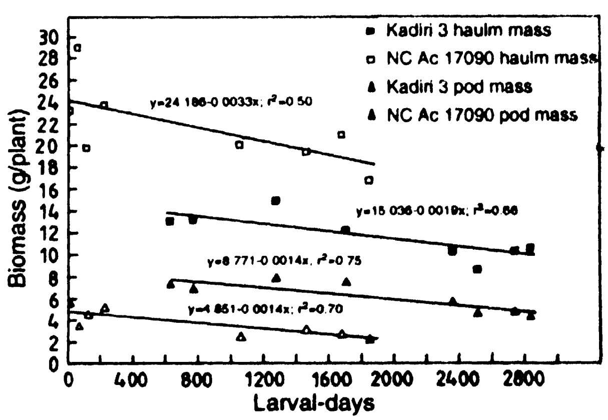

Fig. 3. Regression of pod and haulm yield on *Aproaerema modicella* cumulative larval density for two groundnut cultivars in south India

intercepts indicate the higher pod yield potential of Kadiri 3. The impact of leafminer on haulm production (Fig. 3) was also not significantly different (Student's t-test; $t = 1.0289$; $n = 16$) between the two cultivars. Haulm yields in the two cultivars were reduced at similar rates as leafminer densities increased.

The number of pods per plant (Table 2) was higher ($P < 0.05$) in sprayed plots than in unsprayed plots for both cultivars. Untreated plots had fewer pods, and mature pods per plant, relative to treated plots, though the percentage of mature pods was similar across treatments for the same cultivar (Table 2). Fruit growth rates (g/pod/day) were not significantly different between treatments (ANOVA; $F_{3,13} = 0.363$; $P > 0.25$). Both cultivars, however, had higher fruit growth rates in the untreated plots relative to the sprayed plots.

Table 2. Effect of insecticide application on pod number/plant in two groundnut cultivars

Treatment	Mature pods[1]	Total pods	Percent mature
Kadiri 3 sprayed	12.7 a	20.4 a	62.2
Kadiri 3 untreated	9.3 b	14.3 c	65.5
NC Ac 17090 sprayed	8.4 b	16.8 b	50.4
NC Ac 17090 untreated	5.9 c	12.1 c	48.4

[1]Means in a column followed by the same letter are not significantly different ($P > 0.05$) according to Duncan's multiple range test.

DISCUSSION

The naturally occurring, high density leafminer population in the 1987 rainy season (Shanower, 1989) enabled its impact on groundnut phenology to be studied under field conditions.

Stem biomass was 30 and 20% lower in untreated plots of Kadiri 3 and NC Ac 17090 respectively compared to sprayed treatments. The rate of stem biomass production was also lower in untreated plots. These results support findings from artificial defoliation studies. Enyi (1975) observed a reduction in stem mass of up to 40%, depending on the time of defoliation, when half of the leaflets were removed from the plants. Stem mass was 20–30% lower in another study when 50% of the leaves were removed artificially (Wilkerson et al., 1984).

Leafminer damage significantly reduced flower and peg production in untreated plots of both cultivars relative to the treated plots. Santos and Sutton (1983) reported lower flower and peg production when plants were defoliated by hand at 12 and 14 weeks after germination, though the magnitude of the reduction was not reported.

Both pod weight and number were lower in plots defoliated by *A. modicella* compared to sprayed plots. The 33% reduction in leaf biomass in Kadiri 3 resulted in 30% fewer pods and 30% lower pod weight. The loss of 10% of leaf biomass in NC Ac 17090 resulted in 25% fewer pods and a 20% reduction in pod weight. Groundnut plants in sprayed plots had more fruit and fruit mass per plant, but the growth rate of individual fruits was lower. Fewer pods were initiated in unsprayed plots due to heavy defoliation, but pods grew at a faster rate. Defoliation reduced the photosynthate supply and changed the allocation pattern in the plant. This resulted in fewer fruits being initiated but allowed more rapid growth of existing fruits (Gutierrez and Curry, 1989).

A linear relationship between leafminer density and both pod and haulm yield was observed in the two cultivars. The effects of additional leafminer larvae were additive, and did not differ between cultivars. This simplifies the task of developing accurate and effective thresholds for this pest. Cultivar NC Ac 17090 did not exhibit tolerance to leafminer (Fig. 3); however, fewer larvae were found on this cultivar, suggesting that it may be less preferred by the leafminer. Antibiosis may also have contributed to the lower leafminer loads recorded on NC Ac 17090. Further research is needed to determine whether antixenosis and/or antibiosis resistance contribute to the moderate levels of resistance to leafminer in this cultivar.

The naturally occurring, high density infestation of *A. modicella* caused extensive defoliation and lower leaf weight, resulting in lower stem weight, fewer pods, and lower pod weight. Although fewer pods were initiated, plants compensated with rapid fruit growth rates in unsprayed plots. These field results support results from artificial defoliation studies (Enyi, 1975; Santos and Sutton, 1983; Wilkerson et al., 1984).

Acknowledgements—We thank the field staff of the Legumes Entomology Unit at ICRISAT for help in data collection and the Rockefeller Foundation for providing fellowship support to the senior author. This paper was approved as Journal Article No. JA-1516 by ICRISAT, Patancheru, Andhra Pradesh 502 324 India.

REFERENCES

Enyi B. A. C. (1975) Effects of defoliation on growth and yield in groundnut (*Arachis hypogaea*), cowpea (*Vigna unguiculata*), soybean (*Glycine max*) and green gram (*Vigna aurens*). *Ann. Appl. Biol.* 79, 55–66.

FAO (1992) *Production Yearbook 1991*. Vol. 39. Food and Agriculture Organisation of the United Nations. Rome, Italy. 330 pp.

Gutierrez A. P. and Curry G. L. (1989) Conceptual framework for studying crop-pest systems. In *Integrated Pest Management Systems and Cotton Production* (Edited by Frisbie R. E., El-Zik K.M. and Wilson L.T.), pp. 37–64. John Wiley & Sons, New York.

Panchabhavi K .S., Nethradhaniraj C. R., Yelishetty Y. and Kulkarni G. K. (1986) Effect of artificial defoliation on pod yield in groundnut. *Indian J. Agric. Sci.* 56, 855–857.

Rajput S. G., Dalaya V. P. and Awate B. G. (1984) Efficacy of different insecticides for the control of groundnut leafminer. *J. Maharashtra Agric. Univ.* 9, 336–337.

Rajput S. G., Dalaya V. P. and Awate B. G. (1985) Field evaluation of synthetic pyrethroids and other insecticides against groundnut leafminer (*Aproaerema modicella* D.). *Pesticides* 19, 34–35.

Santos R. B. and Sutton B. G. (1983) Effect of defoliation on reproductive development of the peanut. *Aust. J. Agric. Res.* 34, 527–535.

Shanower T. G. (1989) The biology, population dynamics, natural enemies, and impact of the groundnut leafminer, *Aproaerema modicella* (Deventer) (Lepidoptera: Gelechiidae), on groundnut in India. Ph.D. dissertation, Univ. of California, Berkeley, USA.

Shanower T. G., Wightman J. A. and Gutierrez A. P. (1993) The biology and control of the groundnut leaf miner *Aproaerema modicella* (Deventer) (Lepidoptera: Gelechiidae). *Crop Protection* 12, 3–10.

Sivasubramanian P. and Palaniswamy G. A. (1983) Studies on the chemical control of groundnut leafminer *Aproaerema modicella* Dev. *Madras Agric. J.* 70, 485–486.

Wightman J. A., Dick K. M., Ranga Rao G. V., Shanower T. G. and Gold C. G. (1990) Pests of groundnut in the semi-arid tropics. In *Insect Pests of Food Legumes* (Edited by Singh S.R.), pp. 243–322. John Wiley & Sons, New York.

Wilkerson G. G., Jones J. W. and Poe S. L. (1984) Effect of defoliation on peanut plant growth. *Crop Sci.* 24, 526–531.

Williams J. H. (1979) The physiology of groundnuts (*Arachis hypogaea* L. cv. Egret). 3. The effect of thinning at different stages of development on reproductive growth and development. *Rhod. J. Agric. Res.* 17, 57–66.

Zar J. H. (1974) *Biostatistical Analysis*. Englewood Cliffs, New Jersey, Prentice-Hall.