J. Aust. ent. Soc., 1991, 30: 123-128

SUSCEPTIBILITY OF SOYBEANS TO DAMAGE BY *NEZARA VIRIDULA* (L.) (HEMIPTERA: PENTATOMIDAE) AND *RIPTORTUS SERRIPES* (F.) (HEMIPTERA: ALYDIDAE) DURING THREE STAGES OF POD DEVELOPMENT

H. B. BRIER and D. J. ROGERS

Department of Primary Industries, P.O. Box 23, Kingaroy, Qld 4610.

Abstract

Caged Davis soybean plants were infested with *Nezara viridula* (L.) and *Riptortus serripes* (F.) (4.4 adults/m) at 3 stages of pod development in 3 experiments in 1987, 1988 and 1989. Bug feeding reduced seed yield and oil content during pod fill, but not during pod elongation or pod ripening. *N. viridula* reduced yields significantly in 1987 and 1988, (183 and 494 kg/ha) but *R. serripes* reduced yields significantly only in 1988 (353 kg/ha). Both species damaged more seeds during pod fill than during any other pod stage, but *N. viridula* damaged more seeds than *R. serripes*. Mean seed weight was reduced only during pod fill. In contrast, the mean weight of undamaged seeds increased during pod fill. This indicated partial compensation by Davis soybeans for damage caused by the above bug species at a density of 4.4 adults/m. Seed oil content, recorded only in 1988, was reduced significantly by *N. viridula*, but not by *R. serripes*.

Introduction

The green vegetable bug, *Nezara viridula* (L.), is a major pest of soybeans in Queensland (Turner and Titmarsh 1979; Evans 1985) and New South Wales (Miller *et al.* 1979) as well as internationally (DeWitt and Godfrey 1972). The current nominal economic threshold (Poston *et al.* 1983) for bugs on soybeans in Queensland is 1 adult or large nymph per metre of row in crops from pod set to the start of haying off (Turner and Titmarsh 1979). A major weakness of this threshold is that it makes no allowance for the stage of pod development at which bugs are detected. Many researchers, e.g. Miller *et al.* (1977), G. Strickland (pers. comm.), Thomas *et al.* (1974), Todd and Turnipseed (1974), and Yeargan (1977), have shown that bug damage is related to the stage of soybean pod development. However, none of them came to clear conclusions as to the stage of pod development most susceptible to bug damage. Before bug control recommendations in soybeans can be refined, this important factor must be clarified. Titmarsh and Lloyd (pers. comm.) showed that field populations of *N. viridula* were most damaging to soybeans during the first week of pod fill. Our study looked at this aspect in more detail by infesting caged soybeans at 3 stages of pod development.

In addition, the current threshold does not allow for differences in damage potential between bug species. Turner and Titmarsh (1979) cite a predominance of *N. viridula*, with only occasional damage by podsucking bugs, *Riptortus* spp., in southern Queensland soybean crops. However, *Riptortus* spp. frequently cause considerable damage to soybeans in tropical Australia (I. Kay pers. comm.; G. Strickland pers. comm.) as well as in southeast Asia (Suharsono and Talekar 1986). As *R. serripes* (F.) has become more important in southern Queensland during the last 10 years it was included in this study for comparison with *N. viridula*.

Materials and methods

The 3 experiments reported here used Davis soybeans planted on 15 January 1987, 8 January 1988, and 10 February 1989 at the Department of Primary Industries Research Station, Kingaroy (152°E, 26°30'S). Seeds were inoculated with a suitable *Rhizobium* strain and the trial areas treated with a banded application of fertiliser (225 kg/ha) containing 13.6% phosphorus and 13.7% potassium. Row spacing was 90 cm and plant density was 40 plants/m.

Two-row 1.8m^3 cages, covered with fibreglass mesh (30% shade), were placed over soybean plants at least 14 d before the commencement of each experiment. In 1987, all insects seen on caged plants were removed by hand. Caged plants were then sprayed with Dipel (*Bacillus thuringiensis*) at 6 kg/ha to kill undetected small lepidopterous larvae. In 1988 and 1989, caged plants were sprayed with methomyl (2.0 L of 225 g/L product/ha), as some bug nymphs escaped detection in 1987.

Caged soybeans were infested with *N. viridula* and *R. serripes* at 4.4 bugs/m for the following stages of pod development: pod elongation (R3-R5 of Fehr and Caviness (1977)), pod fill (R5-R6.5 approx.), and pod ripening (R6.5-Harvest). Pod elongation was defined as being completed when pods were fully elongated, but contained undeveloped seeds. Pod fill was defined as being completed when seeds had reached maximum size, but were still green. These pod stages were chosen because they represent 3 easily recognisable stages of soybean pod development. The durations of these stages over the last 3 years of the study are shown in Table 1. Cages were checked regularly and dead bugs removed and replaced with freshly caught bugs of the same sex and species. Each cage was disinfested at the end of its infestation period by removing all visible bugs and then spraying with endosulfan (2.1 L of 350 g/L product/ha). All treatments, including a control (no adult bugs), were replicated 4 times in randomised block designs and were caged for the duration of each experiment. The bug/pod-stage combinations trialled each year were dependent on the availability of bugs of each species and the number of cages.

To ensure that experimental insects reflected the physiological and reproductive state of individuals in naturally occurring infestations at each pod stage, bugs from field populations were used. All experimental bugs were adults collected the day before being placed in cages. To minimise injury, bugs were collected by hand and kept under observation for 24 h. Any bugs showing signs of injury were excluded from the experiments. The sex ratio in all bug treatments was 1:1 as this was the ratio observed in field populations of both species.

At harvest, pods were hand picked, counted, and shelled. Seeds were categorised with the aid of a microscope as: (a) undamaged and fully expanded; (b) undamaged but not fully expanded; (c) bug damaged; or (d) aborted, i.e. completely flat. Undamaged seeds were categorised as (a) and (b) in case the latter had puncture marks too small to be obvious. Aborted seeds had no obvious puncture marks and corresponded to those described by Daugherty *et al.* (1964). Seeds infected with the fungal pathogen *Phomopsis* spp. were frequently encountered. However, as this disease produces a characteristic purple stain, it was not confused with the green-brown stain associated with bug damage. Where doubt existed as to whether a seed was damaged, the adjacent pod walls were examined for the characteristic black puncture marks made by feeding bugs. These were most visible on the inside of the pods. Seeds within each category were counted and weighed, and 100 seed weights calculated from these 2 parameters.

Pods were subsampled for the assessment of seed damage. In 1987, a subsample comprised 500 randomly selected pods/plot, while in 1988 and 1989 a 125 g subsample was used. Subsamples in all years were of equivalent size. Total seed and pod numbers were calculated from pod subsample data. The remaining pods were mechanically threshed, ensuring all seeds were retained. Seed yields were obtained from the combined weights of these seeds and the seeds assessed for bug damage. In 1988, a composite 100 g seed sample (excluding aborted seeds) was taken for each plot and analysed for oil content on a moisture-free basis.

Table 1. Duration (days) of the pod elongation, pod fill, and pod ripening stages for Davis soybeans (1987-1989).

Pod Stage	1987	1988	1989
Elongation	—[a]	10	11
Fill	22	26	28
Ripening	29	39	—[a]

[a] Not recorded as soybeans not infested with bugs during this stage.

Results

Number of pods

Neither pod development stage nor bug species had any effect on the number of harvested pods in any experiment (data not shown). Very few fallen pods were observed in the experiments.

Number of bug-damaged seeds

In all experiments, both bug species damaged significantly more seeds during pod fill than any other stage of pod development (Table 2). During pod fill, *N. viridula* damaged significantly more seeds than *R. serripes* in every experiment. Neither *R. serripes* in 1988 and 1989, nor *N. viridula* in 1989 damaged more seeds during pod elongation than occurred in the control cages. During pod ripening (1987 and 1988 only), the only significant increase in the number of damaged seeds occurred for *N. viridula* in 1988. During pod ripening, almost all damaged seeds had minimal damage, but during pod fill, the majority of damaged seeds were shrivelled and severely distorted.

The damaged seeds in control cages were attacked by second instar *N. viridula* nymphs. These gained entry to the cages from undetected egg rafts laid on the outside of the mesh covers. All treatments were equally contaminated, and all nymphs were removed before reaching the third instar. This contamination, while unfortunate, was not serious as the early instar nymphs fed on relatively few seeds (1987—6%, 1988—3%, 1989—1%) and had virtually no effect on seed size in control cages (Table 3). In both 1987 and 1988, the mean weight of all seeds in control cages was almost identical to that of undamaged seeds. Furthermore, Miller (1977), Yeargan (1977), and Simmons and Yeargan (1988) all indicate that early instars of *N. viridula* and closely related bug species cause much less damage than adult bugs. The latter study showed that first instar nymphs of the green stink bug, *Acrosternum hilare* (Say) do not feed at all.

The numbers of aborted and undamaged but not fully expanded seeds were unaffected by pod stage or bug species (data not shown), except in 1989 when *N. viridula* significantly increased the number of aborted seeds during pod fill.

Table 2. Number of seeds/m damaged by *N. viridula* and *R. serripes* (4.4 adults/m) at 3 stages of pod development.

Pod stage	Bug species	1987	1988	1989
—	Control*	55.1 a	29.7 a	11.5 a
Elongation	*N. viridula*	—	—	11.5 a
	R. serripes	—	47.7 a	3.8 a
Fill	*N. viridula*	327.9 c	464.3 d	158.0 c
	R. serripes	227.6 b	280.1 c	54.5 b
Ripening	*N. viridula*	117.6 a	165.2 b	—
	R. serripes	115.0 a	73.1 a	—

Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's LSD test).
*Uninfested with adult bugs. A few second instar *N. viridula* nymphs detected and removed before they reduced yield (see text).

Table 3. 100 seed weights (g) of seeds from soybeans infested with *N. viridula* and *R. serripes* (4.4 adults/m) at 3 stages of pod development.

		All Seeds*		Undamaged Seeds	
Pod stage	Bug species	1987	1988	1987	1988
—	Control†	17.07 a	21.34 a	17.55 a	21.94 a
Elongation	*R. serripes*	—	21.94 a	—	22.89 ab
Fill	*N. viridula*	14.97 b	17.31 b	18.87 b	24.20 b
	R. serripes	16.39 a	18.31 b	20.16 c	23.71 b
Ripening	*N. viridula*	17.42 a	21.31 a	18.19 ab	22.32 a
	R. serripes	17.31 a	21.46 a	18.03 ab	22.13 a

Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's LSD test).
* Except aborted seeds
† Uninfested by adult bugs. A few second instar *N. viridula* nymphs detected and removed before they reduced yield (see text).

100 seed weight

Only data from 1987 and 1988 are presented (Table 3). No significant differences were recorded in 1989 as a severe outbreak of soybean rust, *Phakopsora pachyrhizi* Sydow, reduced seed weight by approximately 50% and masked weight reductions due to bug damage. During 1988, both bug species significantly reduced mean seed weight (all except aborted seeds) during the pod fill stage. In 1987, only *N. viridula* caused a significant reduction during pod fill.

In contrast, undamaged fully expanded seeds from plants attacked during pod fill were significantly heavier than those from plants from the control treatment in both years. However, weight differences between seeds from the control cages and those from cages infested during the other 2 stages were not significant. In 1987, undamaged fully expanded seeds from the *R. serripes*/pod fill treatment were significantly heavier than the corresponding seeds from the *N. viridula* treatment. However this trend was not apparent in 1988. In 1987 and 1988, there was almost no difference between mean seed weight and undamaged seed weight for the control treatment. Differences in weight between these 2 seed categories were greatest for the pod fill treatment.

Seed yield and oil content

Because of the soybean rust damage in 1989, only 1987 and 1988 data are presented (Table 4). Seed yield was analysed using pod number as a covariate to minimise the confounding effect of agronomic variability. The use of pod number as a covariate was considered appropriate as pod number is a strong determinate of yield (Burton 1987) and our data showed it to be treatment independent. This successfully removed much of the agronomic variability that has masked the effects of bug damage in earlier small cage studies, e.g. Yeargan (1977).

Table 4. Yield and oil content of seeds from soybeans infested with *N. viridula* and *R. serripes* (4.4 adults/m) at 3 stages of pod development.

Pod stage	Bug species	Yield (kg/ha)		Oil Content (%)
		1987	1988	1988
—	Control*	1620 ab	2432 a	19.63 a
Elongation	*R. serripes*	—	2420 a	19.50 a
Fill	*N. viridula*	1437 c	1938 b	18.33 b
	R. serripes	1503 bc	2079 b	18.80 ab
Ripening	*N. viridula*	1640 a	2465 a	19.73 a
	R. serripes	1609 ab	2451 a	19.78 a

Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's LSD test).
* Uninfested by adult bugs. A few second instar *N. viridula* nymphs detected and removed before they reduced yield (see text).

Yields were reduced only during pod fill. *N. viridula* reduced yields significantly in both 1987 and 1988 but *R. serripes* reduced yields significantly only in 1988. In 1987 and 1988, there were no indications of any yield losses from *R. serripes* during pod elongation or from either species during pod ripening.

Yield loss per bug during pod fill was calculated from the seed yield data to compare the damage potential of the 2 species in 1987 and 1988 (Table 5). These data indicate that during pod fill, *R. serripes* causes approximately two-thirds of the damage caused by *N. viridula* (1987—63.9%, 1988—71.5%). However, this difference was not statistically significant at the 5% level in either year.

In 1988, seed oil content was reduced significantly only during pod fill and only by *N. viridula* (Table 4). At 4.4 bugs/m, *N. viridula* reduced oil content from 19.63% to within 0.33% of the soybean industry minimum standard of 18% (Miller *et al.* 1977).

Table 5. Yield loss per bug (g) caused by *N. viridula* and *R. serripes* during pod fill.

Species	1987	1988
N. viridula	3.74 ab	10.10 c
R. serripes	2.39 a	7.22 bc

Means followed by the same letter are not significantly different at the 5% level (Fisher's LSD test).

Discussion

Soybeans are clearly most susceptible to bug attack during pod fill. Both *N. viridula* and *R. serripes* damaged significantly more seeds during pod fill than during any other stage of pod development. As well, pod fill was the only stage in which significant reductions in yield, mean seed weight, and oil content occurred. The undamaged seed weight data indicate that soybeans can partially compensate for bug damage during pod fill. The maximum degree of compensation recorded here, 15%, is lower than the 44% recorded by Russin *et al.* (1987). However, the work by Russin *et al.* (1987) indicated that compensation is related to bug numbers. It is also likely to be affected by soybean cultivar and environmental factors. Comparisons of compensation results from different experiments should therefore be made with caution.

The data show that *N. viridula* and *R. serripes* populations of 4.4 adults/m do not reduce soybean yields during pod ripening. The failure of bugs to reduce yield during this crop stage has been widely reported (Miller *et al.* 1977; Thomas *et al.* 1974; Todd and Turnipseed 1974; Yeargan 1977). The data also indicate that *R. serripes* and *N. viridula* do not significantly damage soybeans during pod elongation at densities of 4.4 adults/m. While seed yield and quality data is for *R. serripes* only

(1988), *R. serripes* in 1988 and 1989 and *N. viridula* in 1989 had no effect on damaged seed, aborted seed, or pod numbers. Yield reductions can only be affected by increases in the former 2 and/or decreases in the latter damage parameters. In the absence of such trends, it is reasonable to assume that 4.4 adult *N. viridula*/m do not reduce yield during pod elongation. This appears to contradict Thomas *et al.* (1974) and Yeargan (1977). These researchers reported significant yield losses for soybeans infested with *N. viridula* from early pod elongation onwards but presented no data specific to either pod elongation or the ensuing pod fill stage. In contrast, the failure of *N. viridula* and *R. serripes* to reduce pod numbers during pod elongation or any other pod stage agrees with Daugherty *et al.* (1964) and Corso *et al.* (1978).

Bug populations in soybeans in south-east Queensland usually increase as pods develop (R. Velasco, pers. comm.). While 4.4 bugs/m would be a high population density during pod elongation, this figure is frequently exceeded during later stages of pod development, particularly during pod ripening. However, our data indicate no yield loss during pod ripening at 4.4 bugs/m (Tables 3 and 4). In addition, more recent studies (Brier and Rogers, unpubl. data) show that *N. viridula* populations of up to 16 adults/m have no effect on soybean yield during pod ripening.

N. viridula is clearly a more serious pest than *R. serripes*, damaging more seeds and causing greater reductions in seed yield and oil content. The yield losses per *N. viridula* during pod fill (1987—3.74 g/bug, 1988—10.10 g/bug) bracket the value of 5.7 g/bug, derived from data presented by Titmarsh and Lloyd (pers. comm.). These authors express yield loss as loss per cumulative bug week per row metre (70 cm row spacing) and give a value for *N. viridula* of 22.36 kg/ha. To convert this to loss per bug, the following calculation was used:

Loss per bug $= (22.36 \times 1000 \times 25.5)/(14286 \times 7) = 5.7$g

where 1000 converts kg to g, 14286 = no bugs/ha if 1 bug/m in rows 70 cm apart, 7 converts loss per week to loss per day, and 25.5 = average duration (days) of pod fill from our experiments (not recorded by Titmarsh and Lloyd). The calculations assume all damage is confined to pod fill.

For both species, the yield loss per bug differed significantly between years. However, differences between species were comparable across years, yield loss per *R. serripes* being 64% and 72% of that per *N. viridula* in 1987 and 1988 respectively. This suggests that seasonal factors may affect yield loss due to bugs and this aspect warrants further investigation.

In conclusion, our findings have important implications for bug control in soybeans. Clearly pod fill is the critical stage for soybeans, and bugs should be controlled before this stage is reached. Because damage is restricted to pod fill, the damage potential of bugs declines as pod fill progresses, and economic thresholds should be increased accordingly. Once pod fill is completed, soybeans are not at risk and control is not warranted. The only exceptions to this would be soybeans grown for planting seed and for the edible seed trade. However, in most cases the optimum time for control would be towards the end of pod elongation, i.e. about 7 days after the commencement of podding. Such a timing would reduce the chance of bug reinfestation during pod fill as well as killing bugs before any damage occurred during this susceptible stage.

Acknowledgments

We are indebted to Mr J. Wessels and Mr M. Marshall for technical assistance. This research was funded in part by the Oilseeds Research Council.

References

BURTON, J. W. (1987)—Results relevant to soybean breeding. *In* Wilcox, J. R. (Ed). *Soybeans: Improvement Production and Uses*. 2nd edn. **6**: 211-247. Agronomy Monograph No 16. Am. Soc. Agron.: Madison.

CORSO, I. C., PORTO, M. D. M., HEINRICHS, E. A. and LEHMAN, P. S. (1978)—Combined effects of bugs and fungi on dropping of pods and the yield components of soybean (*Glycine max* (L.) Merrill). *Anais Soc. Ent. Brasil* **7**: 105-114.

DEWITT, N. B. and GODFREY, G. L. (1972)—The literature of arthropods associated with soybeans. II. A bibliography of the southern green stink bug, *Nezara viridula* (Linnaeus) (Hemiptera: Pentatomidae) *Ill. Nat. Hist. Surv. Biol. Notes* **78**: 1-23.

DAUGHERTY, D. M., NEUSTADT, M. H., GEHRKE, C. W., CAVANAH, L. E., WILLIAMS, L. F. and GREEN, D. E. (1964)—An evaluation of damage to soybeans by brown and green stink bugs. *J. econ. Ent.* **57**: 719-722.

EVANS, M. L. (1985)—Arthropod species in soybeans in southeast Queensland. *J. Aust. ent. Soc.* **24**: 169-177.

FEHR, W. R. and CAVINESS, C. E. (1977)—Stages of soybean development. *Iowa State Univ. Coop. Ext. Serv. Spec. Rep.* **80**: 1-12.

MILLER, L. A., ROSE, H. A. and MCDONALD, F. J. D. (1977)—The effects of damage by the green vegetable bug, *Nezara viridula* (L.) on yield and quality of soybeans. *J. Aust. ent. Soc.* **16**: 421-426.

MILLER, L. A., ROSE, H. A. and MCDONALD, F. J. D. (1979)—A sweep net survey of soybean insects, north west slopes and plains region, New South Wales. *Gen. Appl. Ent.* **11**: 9-12.

POSTON, F. L., PEDIGO, L. P. and WELCH, S. M. (1983)—Economic injury levels: reality and practicality. *Bull. ent. Soc. Am.* **29**: 49-53.

RUSSIN, J. S., LAYTON, M. B., ORR, D. B. and BOETHEL, D. J. (1987)—Within-plant distribution of, and partial compensation for, stink bug (Heteroptera: Pentatomidae) damage to soybean seeds. *J. econ. Ent.* **80**: 215-220.

SIMMONS, A. M. and YEARGAN, K. V. (1988)—Feeding frequency and feeding duration of the green stink bug (Hemiptera: Pentatomidae) on soybean. *J. econ. Ent.* **81**: 812-815.

SUHARSONO and TALEKAR, N. S. (1986)—Preliminary studies of antibiosis of some soybean cultivars to *Riptortus clavatus. Agrivita* **8/9**: 14-16.

THOMAS, G. D., IGNOFFO, C. M., MORGAN, C. E. and DICKERSON, W. A. (1974)—Southern green stink bug: influence on yield and quality of soybeans. *J. econ. Ent.* **67**: 501-503.

TODD, J. W. and TURNIPSEED, S. G. (1974)—Effect of southern green stink bug damage on yield and quality of soybeans. *J. econ. Ent.* **67**: 421-426.

TURNER, J. W. and TITMARSH, I. (1979)—When is a soybean 'pest' a pest? *Qd agric. J.* **105**: 355-362.

YEARGAN, K. V. (1977)—Effects of green stink bug on yield and quality of soybeans. *J. econ. Ent.* **70**: 619-622.

[*Manuscript received* 30 *March* 1990.]