

Inheritance and Selection of Nonpreference Resistance to the Cowpea Curculio in the Southernpea (*Vigna unguiculata* (L.) Walp.)^{1,2}

R. L. Fery and F. P. Cuthbert, Jr.³

U. S. Vegetable Laboratory, Science and Education Administration, U. S. Department of Agriculture, Charleston, SC 29407

Additional index words. insect resistance, *Chalcodermus aeneus*

Abstract. The southernpea breeding line, CR 18-13-1, a source of nonpreference resistance to the cowpea curculio, was crossed with the susceptible breeding line, Fla. 589.06. The F₁, F₂, and backcross progenies of this cross and the parental lines were grown in outdoor screen-cage and field tests over a 3-year period. Large error variances were noted in all tests because of apparent plant-to-plant variation in number of curculios. Resistance was inherited in a partially dominant manner and broad-sense heritability estimates ranged from 0.0 to 19.1%. Selection in the seedling stage for low amounts of adult curculio feeding damage increased the frequency of resistant plants.

The cowpea curculio, *Chalcodermus aeneus* (Boh.), is the most serious insect pest of the southernpea, *Vigna unguiculata* (L.) Walp., in the southeastern U. S. Feeding and oviposition activities of the adult greatly reduce the quality of the processed or fresh market product and the presence of larvae constitutes a serious contamination problem. Also, the adult is responsible for much of the Choanephora pod rot in southernpeas because the feeding and oviposition punctures provide the entry points needed by the fungus, *Choanephora cucurbitarum* (Berkeley et Ravenel) Thaxter, for infection of the pods (8, 12). At present insecticides are the only effective control measures available. Heavy dependence upon insecticides could be alleviated by the development and use of resistant cultivars.

Cultivar differences in resistance to the cowpea curculio have been reported (1, 4, 5, 10, 16, 17). Cuthbert and Davis (6), Chalfant et al. (3), Cuthbert et al. (9), Ennis and Chambliss (11), and Rymal and Chambliss (15) studied the mechanisms of resistance and delineated several factors that contributed to resistance. Most important were a pod factor that inhibited penetration through the pod wall by adult insect and a nonpreference factor that reduced the number of attempted feeding and ovipositional punctures per pod. Preliminary work of Cuthbert and Davis (6) indicated that it might be possible to select for the nonpreference factor in the seedling stage. Fery and Cuthbert (13) studied the inheritance of the pod factor resistance. This paper reports studies of the inheritance and selection of the nonpreference factor.

Materials and Methods

The data reported here are from 3 field or outdoor screen-cage tests conducted at the U. S. Vegetable Laboratory, Charleston, South Carolina, during the years 1973, 1974, and 1975. Plants of the parental, F₁, F₂, and backcross generations of the cross CR 18-13-1 × Fla. 589.06 were tested for resistance to the cowpea curculio. CR 18-13-1 is one of the best sources of nonpreference resistance to the curculio and typically receives about 70% fewer punctures per pod than susceptible checks (7). Fla. 589.06 is highly susceptible to the curculio. Seeds of the parental, F₁, F₂, and backcross generations were produced using standard crossing (included reciprocals) and

selfing procedures. Routine cultural practices were followed in all tests.

Test I. Parents and progeny were grown in an 18 × 29 m outdoor screen cage stocked with about 2,000 curculio adults. The experimental design was a randomized complete block with four replications, each containing 12 plots. Each replicate contained 1 plot of each of the parents and F₁ and 3 plots of each backcross and F₂ generation. Twenty seeds per plot (13 seeds for the F₁ × CR 18-13-1 backcross population) were planted 30 cm apart on beds 73 cm apart. Pods were collected from each plant as soon as they reached the mature green stage at which they are normally harvested for fresh market. The number of pods and the number of punctures in the pods were recorded. Damage ratings were expressed as the number of punctures per pod.

Test II. Seed of the parental, F₁, and F₂ populations were planted in 40 × 66 cm trays (100 seed per tray). Some of the F₂ trays were enclosed with mesh screen covers and infested at initial plant emergence (3 days after seeding) with 150 adult curculios per tray. The adults were allowed to feed for 3 days and the best (those fed on least) 20% of the seedlings were selected. These seedlings, together with random seedlings from uninfested parental, F₁ and F₂ populations, were transplanted into 20 cm (diam) plastic pots spaced 120 cm apart in a 9 × 36 m outdoor screen cage. A completely randomized experimental design was used. The nonsegregating (parental and F₁ populations contained 40 plants each and the segregating (F₂ and selected F₂) populations, 100 plants each. Field-collected adults were released in the cage at anthesis and the insect population was maintained at about 2 adults per plant. Data were collected in the same manner as in Test I.

Test III. Jiffy-Seven pellets containing greenhouse-grown 7-day-old seedlings of the parental, F₁, F₂, and backcross populations were transplanted into a field naturally infested with the cowpea curculio. The experimental design was a randomized complete block with 4 replications, each containing 15 plots. Each replicate contained 2 plots of each parent and F₁ and 3 plots of each backcross and F₂ generation. Twenty plants per plot (12 for the F₁ × Fla. 589.06 backcross population) were planted 38 cm apart on beds 1 m apart. Data were collected in the same manner as in Tests I and II.

Results and Discussion

The reactions of the 2 parent lines to the cowpea curculio infestations were as expected in all tests. In Tests I, II, and III the resistant parent CR 18-13-1 received 51, 66, and 86%, respectively, fewer punctures per pod than the susceptible parent Fla. 589.06 (Table 1). Initial evaluations, however,

¹Received for publication November 25, 1977.

²Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

³Research Geneticist and Research Entomologist (retired), respectively.

Table 1. Population sizes, means, standard errors (SE), and coefficients of variability (CV) for number of cowpea curculio punctures per pod in the parental, F₁, F₂, and F₁ × P₁ and F₁ × P₂ backcross populations for Tests I, II, and III.

Population	No. of plants	Mean ± SE	CV
<i>Test I</i>			
P ₁ CR 18-13-1	80	1.72 ± 0.25	131.18
P ₂ Fla. 589.06	75	3.54 ± 0.33	81.16
F ₁	79	2.17 ± 0.26	108.78
Midparent	—	2.63	—
Avg F ₁ & P ₁	—	1.94	—
Avg F ₁ & P ₂	—	2.86	—
F ₂	230	2.82 ± 0.19	99.70
F ₁ × P ₁	142	2.85 ± 0.25	105.47
F ₁ × P ₂	231	3.49 ± 0.21	90.56
<i>Test II</i>			
P ₁	38	2.02 ± 0.37	111.88
P ₂	38	5.89 ± 1.05	109.68
F ₁	38	2.23 ± 0.40	110.76
Midparent	—	3.96	—
F ₂	98	5.01 ± 0.69	136.93
F ₂ (selected) ^z	100	3.89 ± 0.47	117.09
<i>Test III</i>			
P ₁	151	0.22 ± 0.03	142.06
P ₂	159	1.52 ± 0.11	90.42
F ₁	149	0.71 ± 0.08	131.81
Midparent	—	0.87	—
Avg F ₁ & P ₁	—	0.46	—
Avg F ₁ & P ₂	—	1.12	—
F ₂	237	0.41 ± 0.04	146.66
F ₁ × P ₁	215	0.34 ± 0.03	140.76
F ₁ × P ₂	140	0.76 ± 0.08	132.41

^zPlants selected in seedling stage for low amounts of cowpea curculio injury.

indicated a serious lack of uniformity among tests. The means of the three segregating populations (F₂, F₁ × P₁, and F₁ × P₂), for example, were considerably greater than their respective midparent (average F₁ and P₁ or P₂ for the backcross populations) values in Test I, but were considerably smaller in Test III. Differences in the mean number of adult curculios per plant to which each population was exposed are the most probable explanation for this lack of uniformity. Because the mean curculio population per plant was determined by the number of adults in the field and the number of plants with vulnerable pods, the large natural fluctuations in the curculio population that occur throughout the season and the small

Table 2. Estimates of environmental variation, total genetic variation, and broad-sense heritability for nonpreference resistance to the cowpea curculio for Tests I, II, and III.

Statistic ^z	Estimated value		
	Test I	Test II	Test III
Environmental variation ^y	107.59	110.77	120.84
Total genetic variation	0.00	26.16	25.82
Broad-sense heritability	0.0%	19.1%	17.6%

^zThe coefficient of variation and not the variance used as a measure of variation.

^yWeighted average of the coefficients of variation of the three non-segregating populations (P₁, P₂, and F₁).

Table 3. Frequency distributions for number of cowpea curculio punctures per pod in the unselected (theoretical) and selected (observed) F₂ populations of Test II.

Population	Number of punctures		
	≤2.39	2.40–4.83	≥4.84
<i>Frequency of plants</i>			
F ₂ (unselected) ^z	42.9	25.5	31.6
F ₂ (selected) ^y	51.0	21.0	28.0

$\chi^2 = 2.73$; probability is between 0.30 and 0.20.

^zDistribution adjusted to give the same total frequency as the selected (observed) F₂ population.

^yPlants selected in the seedling stage for low amounts of cowpea curculio injury.

differences in the mean maturity dates of the segregating populations are important determinants of the amount of damage received by any particular plant population. Also, the pod is vulnerable to attack for only the last few days of development, and the damage sustained is directly related to the mean adult population per plant over a very short time span. It is conceivable, for example, that plants differing in maturity by only a few days could be subjected to vastly different insect population pressures.

None of the data from Tests I, II, or III was fully amenable to detailed biometrical analyses. The data were not additive and the population variances were related to the means (variances increased as the means increased). No simple change of scale could be found that would satisfy the ABC scaling tests (or coarser tests) of Mather and Jinks (14) for conformity with the additive-dominance model. Since many of the differences in variances between the nonsegregating populations (P₁, P₂, and F₁) could be removed by using the coefficients of variation rather than the variances themselves as measures of variation (14), the assumption was made that this transformation would provide a relative measure of dispersion so that the variation of plant populations measured under different mean curculio population pressures could be compared. Additionally, it was felt that the data were extensive enough and collected over a sufficiently long period that broad-sense heritability estimates calculated using these coefficients of variation should be of considerable practical value to the plant breeder.

Inheritance of resistance. No significant differences were noted between reciprocal crosses or replicates and all reciprocals and replicates were combined for genetic analyses. The F₁ means in all three tests showed some degree of dominance toward the resistant parent and away from the midparent values, indicating the nonpreference resistance to the cowpea curculio is inherited in a partially dominant manner (Table 1). Broad-sense heritability estimates were low and ranged from 0.0 to 19.1% (Table 2).

Seedling screening. Comparison of the selected and unselected F₂ populations in Test II indicated that both the mean and frequency distribution were affected by selection in the seedling stage for low amounts of feeding damage. The average number of curculio punctures per pod was decreased by 22% (Table 1) and the frequency of resistant plants (≤2.4 punctures per pod) was increased by 19% (Table 3). Although these differences were not statistically significant, the magnitude and direction of the changes that resulted from just a single selection cycle must be interpreted as supportive of the practicality of the seedling screening procedure proposed by Cuthbert and Davis (6).

Conclusions

Progress toward development of southernpea cultivars with

nonpreference resistance to the cowpea curculio using the classical pedigree system of breeding a self-pollinated crop is likely to be slow if selections are made under field conditions. Early-generation single-plant selection schemes are likely to be quite inefficient because of low heritabilities and large variability in the curculio population from plant-to-plant. Breeding systems, e.g. single seed descent (2), in which selection is delayed until after homozygosity is reached would allow more meaningful evaluations to be made on a family rather than a single-plant basis. Selection in the seedling stage could well be a practical alternative to field selection and a more definitive investigation into the relationship between seedling and pod preferences of the adult cowpea curculio is warranted.

Literature Cited

1. Arant, F. S. 1938. Life history and control of the cowpea curculio. *Ala. Agr. Exp. Sta. Bul.* 246.
2. Brim, C. A. 1966. A modified pedigree method of selection in soybeans. *Crop Sci.* 6:220.
3. Chalfant, R. B., E. F. Suber, and T. D. Canerday. 1972. Resistance of southern peas to the cowpea curculio in the field. *J. Econ. Entomol.* 65:1679-1682.
4. _____ and T. P. Gaines. 1973. Cowpea curculio: Correlations between chemical composition of the southern pea and varietal resistance. *J. Econ. Entomol.* 66:1011-1013.
5. Cuthbert, F. P., Jr., and O. L. Chambliss. 1972. Sources of cowpea curculio resistance in *Vigna sinensis* and related species. *J. Econ. Entomol.* 65:542-545.
6. _____ and B. W. Davis. 1972. Factors contributing to cowpea curculio resistance in southern peas. *J. Econ. Entomol.* 65:778-781.
7. _____ and R. L. Fery. 1975. CR 17-1-13, CR 18-13-1, and CR 22-2-21. Cowpea curculio resistant southernpea germplasm. *HortScience* 10:628.
8. _____ and _____. 1975. Relationship between cowpea curculio injury and *Choanephora* pod rot of southern peas. *J. Econ. Entomol.* 68:105-106.
9. _____, _____, and O. L. Chambliss. 1974. Breeding for resistance to the cowpea curculio in southern peas. *HortScience* 9:69-70.
10. Dupree, M. and C. M. Beckham. 1955. The cowpea curculio — a pest of southern peas. *Ga. Agr. Exp. Sta. Tech. Bul., new ser.* 6.
11. Ennis, T. H., and O. L. Chambliss. 1976. Pods resist insect penetration in curculio resistant southern peas. *Auburn Univ. Ala. Agr. Expt. Sta. Highlights Agr. Res.* 23:8.
12. Fery, R. L., and F. P. Cuthbert, Jr. 1972. Association of plant density, cowpea curculio damage and *Choanephora* pod rot in southernpeas. *J. Amer. Soc. Hort. Sci.* 97:800-802.
13. _____ and _____. 1975. Inheritance of pod resistance to cowpea curculio infestation in southernpeas. *J. Hered.* 66:43-44.
14. Mather, K., and J. L. Jinks. 1971. Biometrical genetics. Cornell University press, Ithaca, N. Y.
15. Rymal, K. S., and O. L. Chambliss. 1976. Cowpea curculio feeding stimulants from southernpea pods. *J. Amer. Soc. Hort. Sci.* 101:722-724.
16. Todd, J. W., and T. D. Canerday. 1968. Resistance in southern peas to the cowpea curculio. *J. Econ. Entomol.* 61:1327-1329.
17. Wolfenbarger, D. A., and R. T. Correa. 1963. Variations in southern pea varieties to cowpea curculio infestations. *Tex. Agr. Expt. Sta. Progr. Rpt.* 2286.

J. Amer. Soc. Hort. Sci. 103(3):372-374. 1978.

Influence of Nitrogen, Deblossoming, and Growth Regulator Treatments on Growth, Flowering, and Runner Production of the 'Gem' Everbearing Strawberry¹

E. Tafazoli and B. Shaybany²

Department of Horticulture, Pahlavi University Shiraz, Iran.

Additional index words. *Fragaria* X *ananassa*, gibberellic acid, (2-chloroethyl) phosphonic acid, ethephon

Abstract. Uniform everbearing strawberry plants (*Fragaria* x *ananassa* Duch. cv. 'Gem') were treated with 60 and 100ppm N, 50 and 100ppm gibberellic acid (GA₃), and 50 and 100ppm (2-chloroethyl) phosphonic acid (ethephon) in the greenhouse. One half of the plants were deblossomed as flowers emerged. Both GA₃ and N increased runner production and vegetative growth, independently and without interaction. Ethephon and deblossoming were generally ineffective on the measured characters except that 100ppm ethephon reduced leaf fresh weight and deblossoming increased inflorescence number. Highly significant interactions were observed among ethephon and higher levels of GA₃ and N. 'Gem' flowering and runner production appear independent of each other with deblossoming of no practical value in promoting runner production.

Everbearing strawberries are shy runner producers. This is thought to be due to continuous initiation of flowers during the growing season and as a horticultural practice, flower buds are removed to favor runner production (3, 12), although one report indicated that this practice had no effect on runner production of 'Redcoat' ever bearing strawberries (4). Furthermore, suggestion has been made that flowering and runner production are independent processes (10). Several experiments have reported that GA₃ stimulates runner development (13) and inhibits flowering of strawberry (5, 11). N has been

reported to increase runner production (2). The present experiment was designed to study the effect of N, gibberellic acid, ethephon, and deblossoming on runner production, growth and flowering of 'Gem' strawberries.

Materials and Methods

Eighty plants of the everbearer 'Gem', 12-14 g fresh wt, were planted in April 1977 in pots filled with potting compost and were grown in a glasshouse under natural long-day conditions of spring and summer with a mean temp of 22°C. Deblossoming, N, GA and ethephon were used at 2 levels each. Urea was added to bring the nitrogen level of the potting compost to either 60 or 120ppm. GA₃ and ethephon at 50 and 100ppm, were applied separately as aqueous solutions,

¹Received for publication Oct. 18, 1977.

²Assistant and Associate Professor, respectively.