Screening for Sweet Potato Weevil Resistance

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Abstract

Since *Cylas* sp. are the major insect pests of sweet potato worldwide, development of resistant cultivars is desirable and has been tried by various research institutions. But the level of resistance is still not satisfactory.

It is felt that one of the reasons why this is the case might be a lack of understanding of the most plant-weevil relationships.

Factors influencing screening results like tuber depth, soil type and season of the year could be identified. Furthermore, the role of the leaf, stems and tuber in the build-up of the weevil population were separately analyzed on selected clones.

Tuber resistance which could be identified, although not satisfactory in the first weevil generation, might influence population build-up negatively over several generations.

Introduction

The sweet potato weevils *Cylas formicarius* and *Cylas puncticollis* are the major pests of the sweet potato-growing areas in the world. According to the Commonwealth Institute of Entomology map (CIE Distribution Map 278), *C. puncticollis* is mainly present in West and Central Africa while *C. formicarius* is pan tropical.

The weevil feeds on the tuber, stem and leaf. Main yield loss occurs by stem and tuber damage. The tunnelling larvae destroys the vascular system of the stem and renders the tuber unfit for consumption. Damage by the insect on 20 percent of the Texas crops, 12 percent of the Louisiana crop and 10 percent of the Florida crop was reported by Chithendin (1919). In India, crop losses can be as high as 90 percent. At IITA (Nigeria) crop losses up to 80% have been reported in experimental plots.

Control of the weevil can be done by crop rotation, earthing up of ridges to reduce access of the weevil to tubers, and insecticides. Long lasting soil insecticides are usually of the chlorinated hydrocarbon group which create residue problems. Organic phosphate and carbonate soil insecticides are now frequently used but are more expensive and usually quickly inactivated.

Sweet potatoes are mostly grown by small farmers who cannot afford costly insecticides and because they require minimum capital input. Therefore, the identification and development of resistance against the weevil offers a practical solution. Even if immunity is not achieved, relative resistance is highly desirable if it can lower the rate of damage due to weevil population infestation.

Field screening for Resistance

Various research institutions have tried to identify the degree of resistance against the weevil, mainly *C. formicarius.* All results obtained at IITA have been with *C. puncticollis* only.

About 1,390 sweet potato cultivars and breeding lines have been evaluated by AVRDC (1975-77). Uniform infestation was realized by introducing weevils into the field on susceptible source rows. Damage was evaluated by slicing the roots of samples and recording the larvae, pupae and adult per kilogram sample. Thirty entries had moderately low infestation levels. None could be marked as highly non-preferred. Cockerham and Deen (1947) reported that over the years, from 1939 to 1946, differences in weevil infestation could be found in seedling varieties, but the level of resistance was only moderate. Jones *et al.* (1978) reported inconclusive results when he tested 75 lines over a 3-year period utilizing natural infestations. Even with artificial infestation, the results were still inconclusive.

Waddill and Conover (1978) found that there were significant differences in five cultivars and 37 selections of white-flesh sweet potatoes. They stated that this might offer possibilities for developing resistant cultivars.

In IITA (Hahn 1971-1974) since 1971 the sweet potato breeding program has given high priority to evaluation of sources of resistance to the sweet potato weevil from the germplasm collection. About 800 entries from Asia, Latin America, North America, and Africa have been evaluated. A tuber damage score ranging from 0-5 has been developed measuring: Class 0 – no visible damage; Class 1 – few feeding punctures and adult emergence holes in upper portions near the neck of tubers in 1% of harvest; Class 2 – small feeding and few adult emergence holes in upper fifth of the whole tubers in 5% of harvest; Class 3 – moderate feeding and increasing number of adult emergence holes on the upper fourth of the tuber in 25% of harvest; Class 4 – extensive feeding and many adult emergence holes in the upper fourth of the tuber in 50% of harvest; and Class 5 – severe feeding and numerous adult emergence in the upper one-third of the tuber in 75-100% of harvest.

Each germplasm entry was planted in 4-meter rows. The clones showing less weevil damage during 1971 and 1972 tests were crossed, re-selected and tested at four locations during the 1973-74 growing seasons. These lines were evaluated in plots 2 x 10 m. The results are shown in Table 1. Field resistance was remarkably improved during these years and further improved until 1978, but the results (Figure 1) indicate that further improvement for this character may be difficult unless new sources of resistance are identified which then can be incorporated into the breeding population and screened with improved screening methods.

All the work mentioned above shows clearly that within the species, *Ipomoea batatas'* sources of resistance are present but the level is, up to now, unsatisfactory. The reason is probably because not enough germplasm has been tested, or possibly our understanding of the host plant-weevil relationship is inadequate. In my opinion, it is certainly true that there must be many more cultivars, especially in South East Asia and

South America, which have not been utilized, but, on the other hand, it is especially true that none of the work mentioned, except for Cockerham *et al.* (1954) has included detailed studies about insect-host plant relationship. This relationship is vital if a realistic screening method is to be developed.

Host Plant Relationship and Factors Influencing Host Plant Resistance

Leaves. As mentioned before, the weevil feeds on the leaf, stem and tuber. Cockerham *et al.* (1954) demonstrated that tubers are preferred over vines and leaves at a ratio of 75% to 11%. This is true only for the last 2 months of the sweet potato growing season when tubers are available. In the first two months, only vines and leaves are available. Other studies failed to take into account differences between males and females feeding habits. Our observations on females indicate that feeding on the tuber is done mainly to prepare egglaying holes while other food intake comes from the stem and leaves.

Other observations made on weevil population reared for 5 generations on tubers alone showed that the vitality goes down. As soon as leaves are fed in addition to the tubers, females lay more eggs. Although these observations were not properly tested, there is an indication that vines and leaves are essential for a balanced diet and, therefore, also are important screening factors which should not be neglected.

Stem and Tuber. *C. puncticollis* breeds in the stem and tuber. As already mentioned during the first months of sweet potato growth, no tubers are available. The weevil depends on the vines only for breeding space. Observations made on 600 stems showed that an average of 3-4 larvae are able to develop in the first 20 cm above ground level. This part is preferred over the soft end vines. The larvae tunnels in the soft pith but not in the vascular bundles. The swelling of the stem, which is very evident in some clones, is not a sign of susceptibility to weevil but a tissue reaction due to the attack. Usually, the swollen tissues is too fibrous to allow larvae to tunnel.

Due to the fact that only a small number of larvae are able to survive in the stem, the build-up of the weevil population is usually slow even when the initial population is high. This stresses the importance of the stem as a source of resistance. High stem resistance could reduce the population considerably and reduce pressure from tubers which are formed later.

In addition, stem damage is the main reason for yield loss. The damage on the vascular system done by feeding, larvae tunnelling and secondary rots reduce the size and number of tubers (Singh, 1973) (Table 2). Actual losses can not be measured solely by yield but loss of quality must also be considered.

The tuber is the main source for breeding but the weevil can only utilize it once it is exposed. *Cylas* species are not able to burrow through the soil. Therefore, the upper part of the tuber below the neck is usually the first part which is attacked. It is not true, as stated by Pillai and Kamalan (1977), at least for *C. puncticollis,* that the weevil reaches the tuber through the neck. The neck is too fibrous for tunnelling larvae.

The exposure of tubers to weevil attack depends on three factors, (1) the depth at which the tuber is formed, (2) the soil type, and (3) the season. The tuber depth is largely a variety characteristic and depends on the length of the tuber neck. Varieties with long necks usually tuberize deeper than those with short necks. Soils with higher clay content tend to shrink when dry and form cracks through which the weevil can enter to reach the tuber. This cracking is enhanced by the growing tuber which needs space. As long as the soil is wet, few, if any cracks appear, but as soon as a dry spell begins, numerous cracks appear in the soil. This is one factor why during the dry season the weevil population increases rapidly (Fig. 2). The other reason is the temperature and humidity. During the wet season, the temperature is fairly low, and the humidity high. Under these conditions, the development of one weevil generation is prolonged and due to the high humidity, a fungus, *Beauveria globulifera,* takes a heavy toll of the adult population.

For screening purposes, these three factors have to be taken into consideration. Deep-rooted cultivars are usually more field resistant than shallow-rooted ones due to this escape mechanism. The beginning of the dry season provides better screening conditions than the rainy season.

Intensive screening on nine field resistant clones

Nine clones have been selected on the basis of performance against weevil attack in previous years and subjected to more vigorous testing methods in the field and in the laboratory.

Trial layout and methods of evaluation

The clones were planted during the first and second seasons in a randomized block design with three replications. Each block measured 7 x 10 m. They were large enough to allow individual weevil population build-up with minimum interference from other blocks. In addition, each block was separated from each other by 2 m spaces planted with cassava.

To ensure a uniform initial infestation, 28 weevil-infested tubers were spread in each block one week after planting. For monitoring the weevil population, two 1 m^2 areas were marked in each block where adults were counted weekly. Both trials were harvested after 4 months. A record of yield, number of infested tubers, stem performance and tuber depth was taken after each harvest.

Results

Figure 2 shows the difference in population build-up between the control, TIb 4 and the average build-up observed on the 9 test clones during the dry season. However, no significant difference could be observed between the control and the test clones during the wet season (1st season), which indicates clearly the importance of the dry season for screening purposes. The build-up of the weevil population increased rapidly after the last rain due to dry cracked soil, higher temperatures and tuber bulking.

The curve of weevil population development (Fig. 2) can be divided into a slow build-up during the first two months influenced by the restricted breeding space in the stem and a rapid increase of the population during the season and half of the growing season when tubers were available. The ratio of the average number of weevils during the first two and second two months is given in Figure 3. Significant differences could be observed during the first 2 months between TIb4 and especially TIS 2079, TIS 3017 and TIS 3290, but the average counts on the test clones of the 2nd period are remarkably equal irregardless of whether the counts were lower or higher during the first two months.

Compared with the control, all test clones showed much lower weevil infestation. These results question the importance of the stem resistance since it didn't influence the population build-up during the 2nd period when tubers were available.

In Figure 4, the damage counted in percent infested tubers has been illustrated. The wet season trial results again indicate clearly that it is not a very suitable time for screening. Differences in infested tubers are lower in the wet season trial compared with the dry season trial although it follows a similar pattern. Since the variation is high among the replications, the trial was repeated this year. The best clones, among the test clones, using TIb 4 as a standard, were TIS 1419, TIS 2079, TIS 3030 and TIS 3017.

As mentioned before, tuber damage depends on various factors. Depending on the factors involved, one can guess about the nature of resistance.

In Table 3 tuber size, average number of weevils and tuber depth are compared with the tuber damage.

In the cases of TIS 1419 and TIS 2079, deep tuberization seems to be the major contributing factor to the observed low damage. Bigger tubers of TIS 1479 contribute to more exposure compared to TIS 2079. Because of these two physical factors, the resistance should be called pseudo-resistance. TIS 3030 has medium size tubers and tuberize fairly shallow. The same applied for TIS 3014 which has large tubers. In both cases, tubers are more likely exposed but in spite of this, are less attacked. Therefore, it is more likely that we are dealing with a sort of mechanical or chemical resistance.

Laboratory Tests

Since significant differences have been observed in the field, stems and tubers of the test clones have been subjected to two laboratory tests to study the host plant weevil relationship in more detail

Stem Test

Stems of each of the nine (9) test clones and TIb 4 were divided into three sections, base, middle and end part. By means of a stem cage in which one female and one male were caged, the stem-part was infested with eggs for 24 hours which then were marked. Then the vine-parts were planted in pots and cut open after 17 days. Differences between number of eggs laid and live larvae were recorded. In terms of egg-laying preference, no differences have been observed in all clones (Tomu, 1979).

Compared with the control, all nine test clones (Fig. 5) showed significant lower larvae survival rates. But among the test clones, no significant differences could be observed. The results then were compared with the average weekly counts during the first two months of sweet potato growth in the field. The differences observed in the lab-test were not reflected in the weevil population development in the field (Fig. 3) (Tomu, 1979). Probably, conditions are more complex outside.

Tuber Lab-test

Since several clones could be identified with fairly high levels of field resistance, a study is presently underway to test whether this resistance has any long term effect on the population development of *C. puncticollis.*

For the first test, 4 test clones which we think have some chemical resistance were compared with the control, TIb 4, without any replication. For each clone, 5 kg of tubers were infested with 20 females and 20 males. Leaves of the same clones were fed for two days. The insects were left in the boxes for 10 days to allow sufficient egg-laying. After 18 days, emerging adults were counted daily and removed. Counting continued for 19 days.

Figure 6 shows clearly a difference in the amount of weevil emerging from TIb4 and the test clones. TIS 2532, TIS 3017 and TIS 3030 behaved very similar while TIS 2079 showed the lowest weevil emergence.

As TIS 2079 has very poor storability, the low results are probably due to rotting of tubers. Therefore, it was discarded in the 2nd test.

The 2nd test included only TIb 4, TIS 3030, TIS 2532 and TIS 3017. Twenty females and 10 males were picked from the F_1 generation of each clone and transferred to the same clone for egg-laying. This time, 4 replications were included with 2 kg of tubers per replication.

The evaluation procedure was the same as in test one. The results, although not shown, clearly indicate differences among the test clones. Compared with TIb 4, emergence of adults was delayed for TIS 3017 and TIS 3030 for 4 days while in the case of TIS 2532, a delay of 6 days was observed. A total of only 22% adults emerged from TIS 2532 compared with the control rate of 100%.

The test is now going into the F_3 generation. The results, up till now, indicate that there might be some factors involved which accumulate over the generations. If the reduced emergence and prolonged development period is projected over a period of 10 generations, the population of TIS 2532 should be reduced to sub-economic levels.

Conclusion

The resistance screening work at IITA has reached a stage where without a detailed knowledge of the host plant-weevil relationship, we were not able to make further progress. Therefore, IITA's focus for the past year has been in this direction. Consistent differences have been observed in the field and in the laboratory between the control or standard clones and the selected resistant clones. Tests in progress have shown that selected resistant clones have an adverse effect on weevil populations by reducing emergence and egg-laying and prolonging the life cycle. These factors could result in population suppression that would significantly reduce weevil damage.

References

ANOTA, T. 1979. Identification of stem resistance against *C. puncticollis* in sweet potato. M.Sc. Thesis, IITA – University of Ibadan. In press.

AVRDC. 1975. Annual Report. Tainan, Taiwan, Rep. of China.

AVRDC. 1977. Annual Report. Tainan, Taiwan, Rep. of China.

CHITTENDEN, F. H. 1919. The sweet-potato weevil and its control. USDA, Farmer's Bulletin, 1020, 24pp. Illustrated.

COCKERHAM, K.L. and DEEN, O.T. 1947. Resistance of new sweet potato seedlings and varieties to attack by the sweet potato weevil. Jour. Econ. Ent. 40(3):439.

COCKERHAM, K. L. DEAN, O.T., CHRISTIAN, M. B. and NEWSOM, L. D. 1954. The biology of the sweet potato weevil. La. Agr. Expt. Sta. Tech. Bul. 483.

HAHN, S.K. 1971-1974. Annual Reports, IITA, Ibadan Nigeria.

JONES, A., CUTHBERT, F. P. JR. and SCHALK, J. M. 1978. U.S. Vegt. Lab., USDA, ARS, Charleston, South Carolina. D. R. Peterson, T. E. Boswell, D. R. Earhardt and M. C. Fugua, Texas A&M Univ., Agric. Res. Ext. Center, Overton. M.A. Mullen and T. R. Arbogast, Sorted-products Insects Lab. USDA, ARS, Savannah, Georgia. Field screening for sweet potato weevil resistance: A progress report. Summary reported in: Hort. Science, Vol. 13(3), 1978.

PILLAI, K. S. and KAMALAM, P. 1977. Screening sweet potato germplasm for weevil resistance. J. Root Crops, 3(1): 65-67.

SINGH, S.R. 1973. Annual report of root and tuber improvement program, IITA, Ibadan, Nigeria.

WADDILL, H. and CONOVER, R.A. 1978. Resistance of white-fleshed sweet potato cultivars to the sweet potato weevil. Hort. Sci., 13(4): 476-477.

Table 1. Yield, percent dry matter and resistance to weevil of IITA sweet potato cones

Clones	Fresh yield (t/ha)	% Dry matter	Dry yield (t/ha)	Weevil score
TIS 2498	23.0	30.2	6.9	1.65
TIS 2534	20.8	26.8	5.6	0.80
TIS 3030	20.2	30.5	6.2	1.00
TIS 3277	19.3	22.5	4.3	3.00
TIS 2544	19.3	27.2	5.2	0.90
TIS 2330	19.0	21.2	4.0	2.30
TIS 1487	18.3	30.4	5.6	2.30
TIS 2532	17.4	29.8	5.2	1.25
TIS 1499	17.0	27.0	4.6	2.50
TIS 3017	16.8	29.4	4.9	1.65
TIS 3247	16.4	28.4	4.7	2.65
TIB 9	15.6	34.1	5.3	1.75
TIB 11	15.5	24.2	3.8	1.65
TIS 3270	15.5	28.0	4.3	2.80
TIS 2153	14.1	35.1	4.9	1.05
TIS 3228	12.7	25.0	3.2	2.40
TIS 1145	12.7	27.9	3.5	3.00
TIS 3290	11.8	34.7	4.1	1.75
TIS 3053	11.2	27.8	3.1	1.30
TIB 2	11.0	25.0	2.8	2.25
TIS 2154	10.6	36.8	3.9	1.75
TIB 10	10.4	29.5	3.1	2.50
TIB 8	8.0	30.4	2.4	2.25
TIB 4	7.9	25.0	2.0	2.30
TIS 2328	4.7			1.25

TIB 4 is the standard cultivar.

Table 2. Damage score and yield of sweet potato as affected by application of foliar insecticides against sweet potato weevil, *Cylas puncticollis*

Treatment	Dry season Damage score	Yield t/ha	Wet season Damage score	Yield t/ha
Didigam EC27	2.2	34.5	2.0	28.3
Lindane WP50	2.2	31.3	2.0	25.1
DDT EC25	2.0	27.7	2.0	24.9
Lannate SP90	3.0	25.5	2.8	20.0
Dieldrin EC20	2.0	24.1	2.0	18.6
Furadan WP75	2.7	22.3	2.6	19.4
Sevin WP 85	2.0	19.8	2.9	10.3
Dursban EC40	2.2	19.4	2.3	15.6
Diazinon EC20	2.2	15.4	2.5	10.4
Control	2.2	14.9	2.8	11.5
LSD at 0.05	1.8	1.6	0.9	1.3

Table 3. Harvest results of wet-dry season trial and factors influencing weevil damage

Clone No.	t/ha	Average Wt./tuber kg	Average No. Weevils/ Week	Tuber depth*	Percent Infested Tubers
TIS 1419	16.6	0.25	11.8	Deep	17.7
TIS 2079	7.7	0.2	8.0	Deep	7.3
TIS 3247	24.4	0.19	8.7	Shallow	33.3
TIS 3030	23.7	0.19	9.4	Medium	16.7
TIS 4	17.5	0.12	24.4	Shallow	73.0
TIS 2534	20.1	0.16	11.7	Medium	36.7
TIS 2544	19.5	0.17	9.4	Medium	32.3
TIS 3290	21.6	0.18	9.0	Shallow	29.7
TIS 3053	20.5	0.24	9.0	Medium	40.3
TIS 3017	23.2	0.27	8.7	Medium	19.0

*shallow, 0-2cm; medium, 2-4cm; deep 4-6cm.

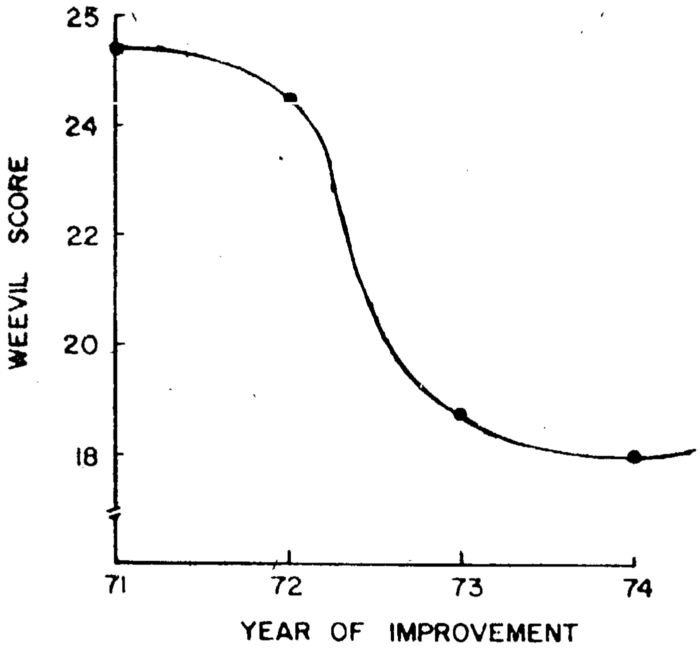

Figure 1. Improvement for field resistance of sweet potato to weevil.

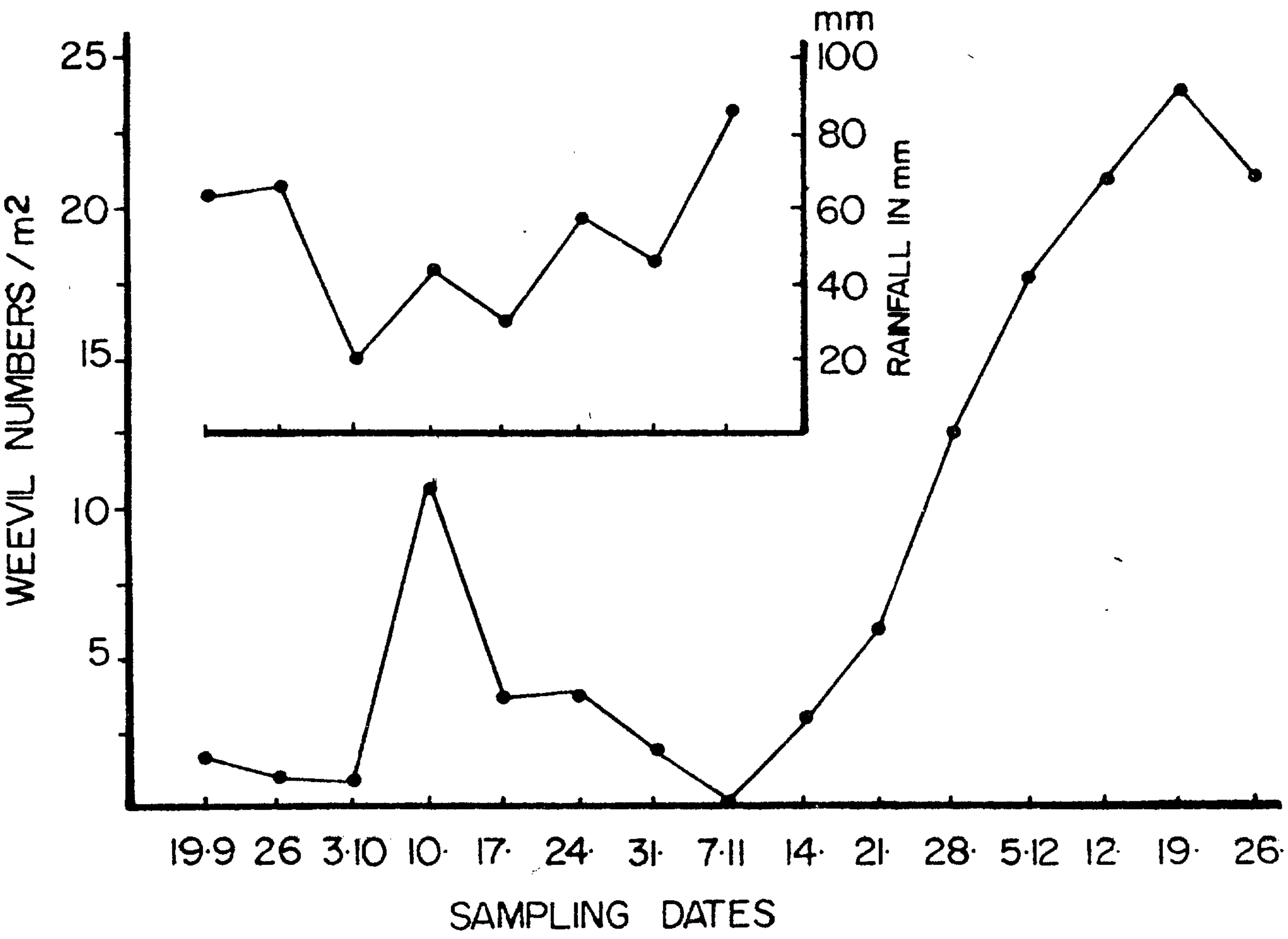

Figure 2. Difference in weekly weevil catches between TIB4 and the average 9 test clones (2nd season)

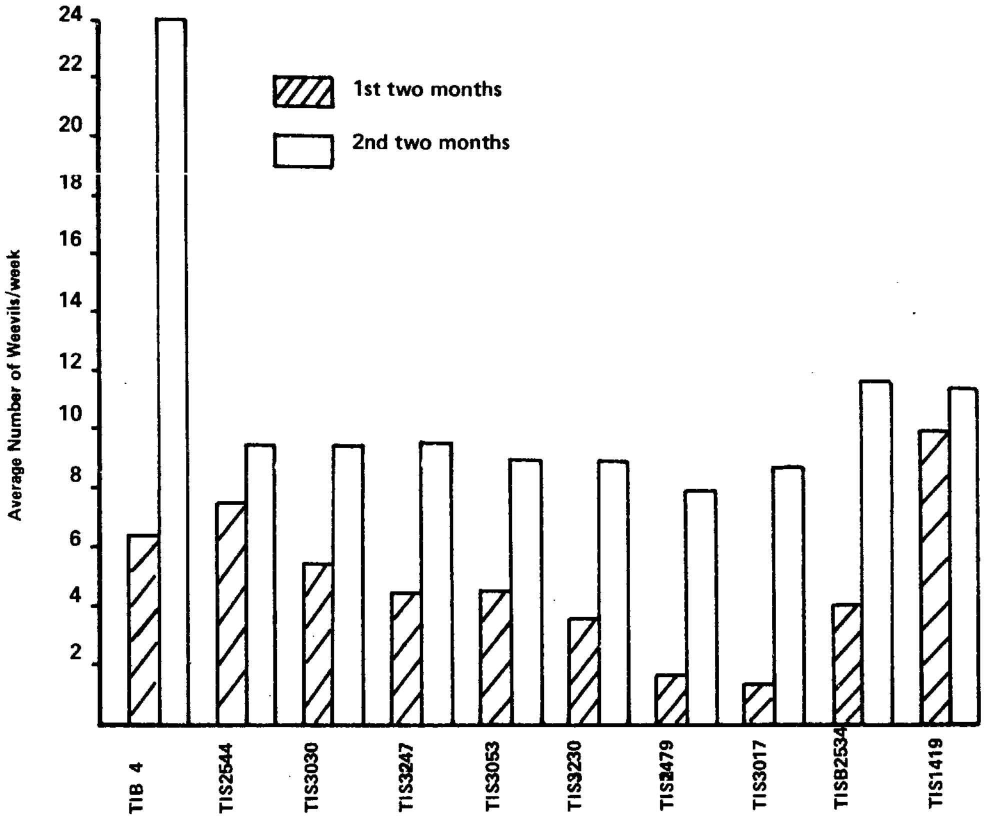

Figure 3. Average weekly catch of weevils during 1st and 2nd two months of plant growth

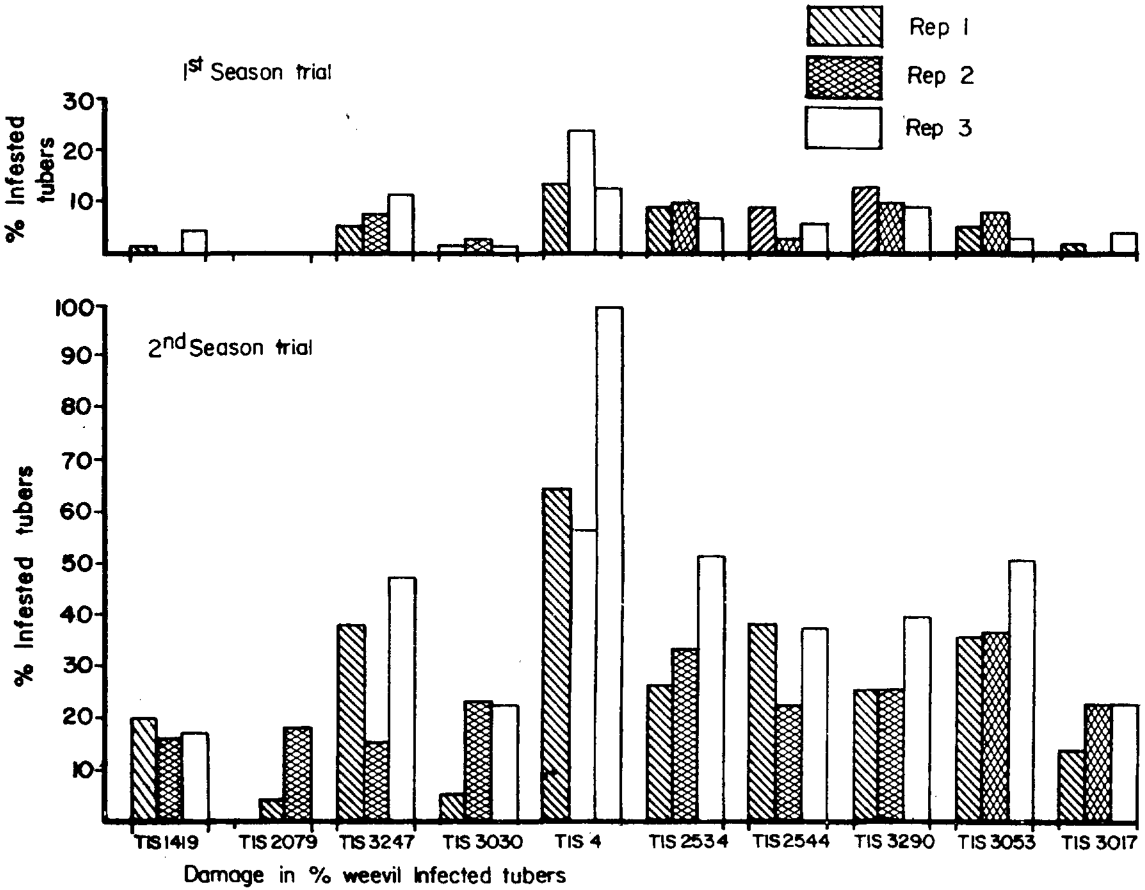

Figure 4. Percent weevil infested sweet potato tubers during 1st and 2nd season

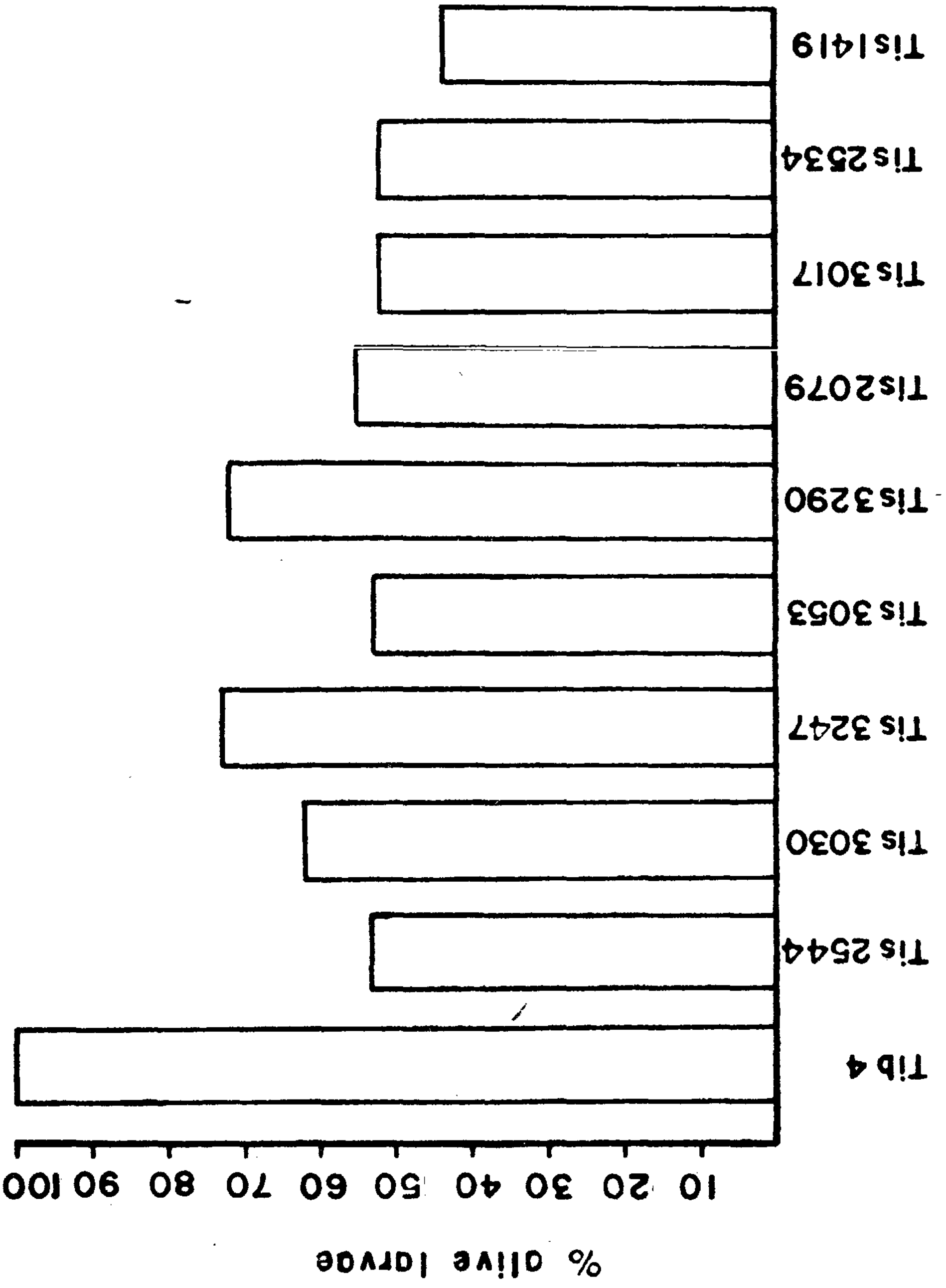

Figure 5. Percent alive larvae obtained from stems of 9 field resistant clones compared with the susceptible sweet potato clone TIB 4

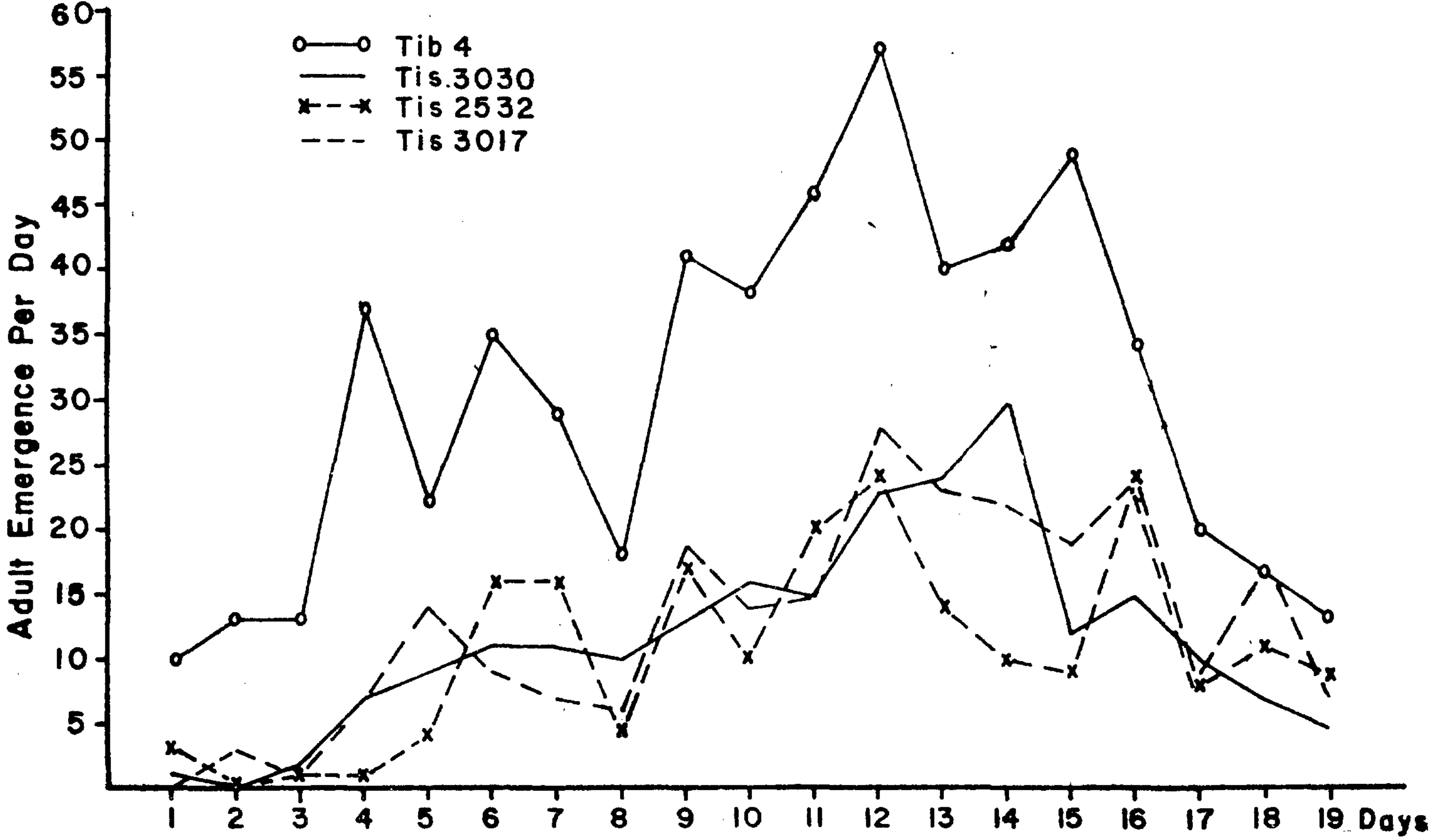

Figure 6. Adult weevils emerging from one susceptible (TIB 4) and three field resistant sweet potato clones under laboratory conditions