EFFECTS OF INTERCROPPING ON A POPULATION OF SWEET POTATO WEEVIL, *Cylas formicarius* (F.) (COLEOPTERA: CURCULIONIDAE)

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ABSTRACT/RINGKASAN

The effect of intercropping sweet potato with corn, soybean, and corn + soybean on the population density of sweet potato weevil and on associated damage was studied. Fewer weevils were found in intercropped sweet potato + corn (2 weevils/kg infected tubers), sweet potato + soybean (21 weevils/kg) than in monoculture sweet potato (37 weevils/kg). Percentage of damaged tubers followed the same trend, ranging from 2.6% to 14.0% in intercropped sweet potato, to 21.9% in the sweet potato monoculture. The intercropped sweet potato, however, had lower yields, from 0.8 t/ha to 2.9 t/ha compared with 7.0 t/ha in the sweet potato monoculture. The economic value of the intercrops was also lower than that of the monoculture suggesting that intercropping sweet potato is not yet a viable alternative cropping system, even though it was effective in reducing numbers of weevils and percentage of damaged tubers.

Pengaruh tumpang-sari ubijalar dengan jagung, kedelai, serta jagung + kedelai terhadap kepadatan populasi kumbang penggerek ubijalar serta kerusakan yang disebabkannya dipelajari. Hanya beberapa kumbang penggerek ubijalar yang ditemukan pada tumpang-sari ubijalar + jagung (2 kumbang/kg umbi yang terinfeksi), ubijalar + kekelai (21 kumbang/kg umbi yang terinfeksi) dan ubijalar + jagung + kedelai (8 kumbang/kg umbi yang terinfeksi), dibandingkan dengan ubijalar monokultur (37 kumbang/kg umbi yang teringeksi).

Persentasi umbi yang rusak mengikuti trend yang sama, berkisar dari 2.6% hingga 14.0% pada ubijalar yang ditumpang-sarikan, hingga 21.9% pada monokultur ubijalar. Akan tetapi tumpang-sari ubijalar mempunyai hasil yang rendah, yang berkisar antara 0.8 t/ha hingga 2.9 t/ha, dibandingkan dengan 7.0 t/ha pada monocultur ubijalar.

Nilai ekonomi yang juga rendah pada tumpang-sari ubijalar dibandingkan dengan monokultur ubijalar menyarankan bahwa tumpang-sari ubijalar belum merupakan suatu sistim pertanaman alternatif yang dapat digunakan, sekalipun sistim tersebut efektif dalam mengurangi jumlah kumbang penggerek ubijalar dan persentasi umbi yang rusak.

INTRODUCTION

Sweet potato, *Ipomoea batatas*, is one of the most important root crops in the province of Irian Jaya of Indonesia, as it is the main staple for its indigenous people, especially for those who live in the highlands (Oomen *et al.*, 1961; Karafir, 1989).

Even though the crop has long been cultivated in Irian Jaya, its production remains insufficient to meet local needs (Karafir, 1989). Low production is often the result of an extra long dry season that coincides with high infestation and damage by the sweet potato weevil, *Cylas formicarius* (F.) (Szent-Ivany, 1958; La Ahmady, 1988).

Chlorinated hydrocarbon insecticides (aldrin & dieldrin) have been used for the control of sweet potato weevil in the lowland region of northern Irian Jaya (van Driest & Ruinard, 1960). Although they were effective, these insecticides do not provide an ideal solution because they are expensive, have numerous negative environmental effects, and pose adoption problems; furthermore, these particular chemicals have subsequently been banned in Indonesia and are likely to be less effective now because of the development of resistance.

The less persistent contact insecticides are ineffective against sweet potato weevil larvae, which live inside the tuber. An alternative approach that avoids these problems involves finding ways to improve a presently practiced cultural control method such as intercropping (Perrin, 1977; Cromatie, 1983).

The effectiveness of intercropping is likely to vary with the species and cultivars of plants used (Singh *et al.*, 1984; AVRDC, 1988). The present study was designed to determine effects of intercropping sweet potato with corn and soybean on population density of sweet potato weevil, level of damage and yield, and to examine the economic implications.

MATERIALS AND METHODS

Site description

Field experiments were conducted during the dry season (July to December, 1989) at the Manggoapi Farm of the Faculty of Agriculture, Cenderawasih University in Manokwari (134°05'E:0°50'S). The farm is 110 m above sea level, with plate topography and a red-yellow Mediterranean soil type, with a pH of 5 to 7. Monthly average for rainfall was 187 mm and number of rainy days was 16 during the field study.

Experimental design and management

The following four treatments were tested using a randomized complete block design with three replicates (150 m^2 plots): A = sweet potato monoculture, B = sweet potato + corn, C = sweet potato + soybean, and D = sweet potato + corn + soybean.

Plant spacing and population density for each treatment are given in Table 1.

Local varieties of all crops were used and were planted simultaneously following local practices. All crops received one or two applications of inorganic sources of nitrogen, phosphorous and potassium. Amounts applied were based on previous research.

Table 1. Spacing and population density of intercrop plants.

Treat-ment[1]	Crop (No. rows)[2]	Sweet potato (SP) Within rows (cm)	Sweet potato (SP) Between rows (cm)	Sweet potato (SP) Plants 150m² plot	Sweet potato (SP) Plants ha	Corn (C) Within (cm)	Corn (C) Between rows (cm)	Corn (C) Plants rows plot	Corn (C) Plants 150m²	Soybean (S) Within harows (cm)	Soybean (S) Between rows (cm)	Soybean (S) Plants 150m² plot	Soybean (S) Plants ha
A	SP(10)	40	100	370	24668	-	-	-	-	-	-	-	-
B	C(2) SP(2) C(2)	40	100	222	14800	50	50	240	16000	-	-	-	-
C	S(3) SP(2)	40	100	222	14800	-	-	-	-	25	25	720	48002
D	S(2) C(1) S(2) SP(2)	40	100	148	9867	50	300	90	6000	25	25	720	48002

[1]A = sweet potato monoculture
B = sweet potato + corn
C = sweet potato + soybean
D = sweet potato + corn + soybean
[2]Repeated across plot

PROCEDURE

Colonization by Sweet Potato Weevils

Colonization of the sweet potato crop by weevils was evaluated at 56 days after planting on 10 randomly selected plants from each plot. A plant was considered colonized if a weevil was present or if weevil damage was evident. Data for percentage colonization were subjected to arcsin transformation prior to analysis of variance (Gomez & Gomez 1984).

Population density of Sweet Potato Weevil and percentage of damaged tubers.

At harvest, ten plants were taken randomly from each plot to determine population density of sweet potato weevil. The tuber and vines (15 cm above the crown) of each plant were dissected and the numbers of weevil larvae, pupae and adults were totalled for the plants from each plot. Percentage of infested (damaged) tubers was calculated for each treatment.

Data for weevil population density and percentage of infected tubers were subjected to square root + 0.5 and arcsin transformation, respectively, prior to analysis. Relationships between these data were analyzed by means of regression analysis.

Number and fresh weight of tubers

Also at harvest, number of tubers from 10 plants selected randomly from each plot and their fresh weights were recorded. Analysis of variance was calculated and the means subjected to Fisher's Least Significant Difference (LSD) test.

Marketable yield

Marketable yields (t/ha) of sweet potato, corn and soybean were calculated for each treatment prior to sale of the produce.

Monetary Index (MI) was calculated according to the following formula (Gomez & Gomez, 1983):

$$MI = \sum_{i=1}^{n}(a_i X_i - b_i)$$

where: a_i = price per unit yield; b_i = cost of production; and X_i = yield for the ith crop.

RESULTS

Colonization of the sweet potato by Sweet Potato Weevil in four cropping systems

Colonization of sweet potato by Sweet Potato Weevil at 56 days after planting was significantly lower in intercropped plots than in the monoculture (Table 2). Although there was no significant difference between the three intercropped treatments, the level of colonization in sweet potato + corn (11%) was half of that in sweet potato + soybean (23%).

Table 2. Colonization of sweet potato by the sweet potato weevil at 56 days after planting.

Treatment		Colonization by Sweet potato weevil (%)
Sweet potato monoculture	(A)	70a*
Sweet potato + soybean	(C)	23b
Sweet potato + corn + soybean	(D)	20b
Sweet potato + corn	(B)	10b

* Means followed by different letters differ significantly at $P < 0.05$ using Fisher's Least Significant Difference test.

Population density of Sweet Potato Weevil and percentage of damaged tubers.

Population density of Sweet Potato Weevil and percentage of damaged tubers were significantly lower in the intercropped plots (treatments B, C and D) than in the monoculture (A; Table 3). These measures were also significantly lower in mixtures containing corn (B & D) than in those without corn (C; Table 3). Although the inclusion of soybean in the sweet potato + corn mixture appeared to reduce this effect, the difference was not statistically significant.

Table 3. Number of sweet potato weevils per kilogram of damaged tubers, and percentage of damaged tubers.

Treatment		Weevils No./kg damaged tubers[1]	Damaged tubers %[2]
Sweet potato monoculture	(A)	37.0 a*	21.9 a*
Sweet potato + soybean	(C)	21.0b	14.7 b
Sweet potato + corn + soybean	(D)	7.7 c	6.6 c
Sweet potato + corn	(B)	2.3 c	2.6 c

[1]Subjected to a square root + 0.5 transformation
[2]Subjected to an arcsin transformation
*Means within columns followed by different letters differ significantly at $P < 0.05$ using Fisher's Least Significant Difference test.

Population density of Sweet Potato Weevil was found to be correlated with percentage of tuber damage (Table 3). This relationship is depicted by the regression line $Y = 2.06 + 0.55\,X$ ($r_{cal.} = 0.98$, $r_{0.05} = 0.87$) (Fig. 1).

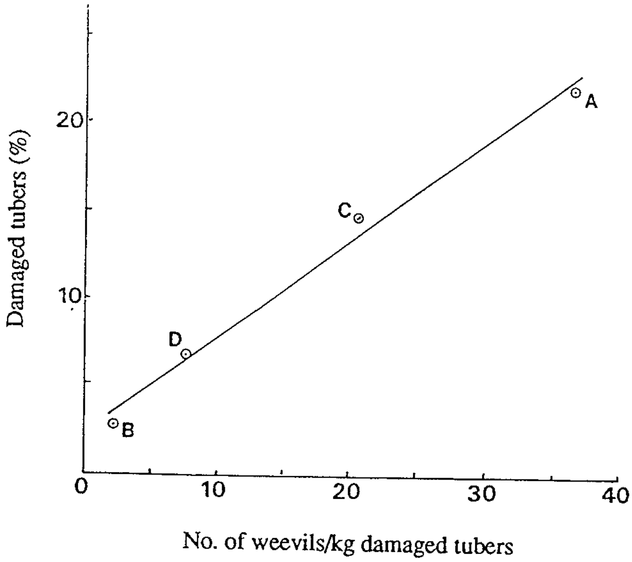

Figure 1. Regression of number of sweet potato weevils on damaged tubers. A = sweet potato monoculture, B = sweet potato + corn, C = sweet potato + soybean, D = sweet potato + corn + soybean.

Number and fresh weight of sweet potato tubers.

Even though the planting of corn with sweet potato (treatments B and D) significantly reduced the population density of Sweet Potato Weevil and number of damaged tubers, level of production measured as number of tubers per plant and as weight of fresh tubers per 10 plants, was significantly lower than in the cropping systems without corn (Table 4). Weight of fresh tubers in the sweet potato + corn + soybean mixture (D: 75.2 gram per 10 plants) was half that in the sweet potato + corn mixture (B: 143.3 gram/10 plants), although this difference was not statistically significant. The inclusion of soybean to the sweet potato + corn mixture (D) appeared to reduce sweet potato yield, in comparison to the sweet potato + corn mixture (B), but it did not affect the number of sweet potatoes produced.

Marketable yield and economic value of sweet potato and intercropped plants.

Marketable yield, economic value and monetary index were highest for the sweet potato monoculture and lowest for the sweet potato + corn + soybean mixture (Table 5). Cost of production was lowest for the sweet potato + corn + soybean mixture and highest for the monoculture.

DISCUSSION

Effects of intercropping on population density of the sweet potato weevil.

The low percentage of weevils colonizing sweet potato intercropped with corn and/or soybean (Table 2) suggests that intercropping may have affected its host searching behavior. For example, percentage colonization by Sweet Potato Weevil, number of sweet potato weevil per plant, and % of damaged tubers in the sweet potato monoculture was around 7, 16 and 8 times that in the sweet potato + corn mixture, respectively (Tables 2 & 3).

Table 4. Effects of intercropping sweet potato on number of tubers per plant and on fresh weight of tubers per 10 plants.

Treatment		Number of tubers per plant	Weight of fresh tubers per 10 plants (g)
Sweet potato monoculture	(A)	2.8 a*	488.1 a*
Sweet potato + soybean	(C)	2.3 a	440.2 a
Sweet potato + corn	(B)	1.1 b	143.3 b
Sweet potato + corn + soybean	(D)	1.1 b	75.2 b

* Means followed by different letters differ significantly at $P < 0.05$ using Fisher's Least Significant Difference test.

Table 5. Marketable yield, economic values, cost of production and monetary index of sweet potato and intercropped sweet potato, corn and soybean.

Cropping system		Marketable yield (t/ha) (X_i) sweet potato	corn	soybean	Economic value (US. $/ha/season)* sweet potato	corn	soybean	Total economic value (US. $)	Cost of production (US. $/ha)	Monetary index (MI)
Sweet potato monoculture	(A)	7.0	-	-	2030	-	-	2030	1177	853
Sweet potato + corn	(B)	0.9	1.6	-	261	656	-	947	970	-23
Sweet potato + soybean	(C)	2.9	-	0.5	841	-	295	1136	1131	5
Sweet potato + corn + soybean	(D)	0.8	0.6	0.3	232	246	177	655	855	-200

*) Market prices for sweet potato, corn, and soybean were 0.29, 0.41 and 0.59 US dollars per kilogram, respectively.
MI = Total economic value - cost of production.

Similar high levels of damage in sweet potato monoculture have been reported in Papua New Guinea (Sutherland, 1986). However, number of tubers per plant, weight of fresh tubers per 10 plants, and total value of market yield in the monoculture were 3, 7 and 3 times that in the sweet potato + corn + soybean mixture and 3, 3 and 2 times that in the sweet potato + corn mixture, respectively (Tables 4 & 5). Profit was also highest with the sweet potato monoculture (US$ 853/ha: Table 5).

Thus, although the mixtures, particularly those including corn, were effective in reducing numbers of Sweet Potato Weevil, they were uneconomic due to low yield per plant, especially when they included both corn and soybean.

The low percentage of colonization and low number of Sweet Potato Weevil in intercropped sweet potato is probably a result of both physical and biological effects of the intercropped plants on the weevils' activity, growth and development (Perrin, 1977, Altieri 1987). The taller corn and soybean plants may act as physical barriers against invasion of the sweet potato crop. The weevils may have moved away from the intercropped sweet potato to more suitable location and they probably had to spend extra time and energy to find their host crop (Kareiva, 1983). In a corn + bean mixture, Parfait & Jarry (1987) found that corn made the microclimate unfavorable for the bean weevil and modified the bean's phenology. Similar effects may be partly responsible for the low sweet potato weevil population in the corn + sweet potato mixture in the present study.

Furthermore, it is suspected that during the extended period of host searching in the intercropped systems, the Sweet Potato Weevil would have been exposed to greater environmental pressures, including higher population densities of natural enemies, than in the monoculture (van Emden, 1990). Predators and parasites are often more abundant within mixtures than in monocultures (Perrin, 1977; Altieri, 1987). Although in the present study, natural enemies were not studied quantitatively, they were recorded qualitatively in both the sweet potato agroecosystems and the surrounding area. For example, preying mantis, which are general predators, were often seen searching for prey on the sweet potato foliage. Also, chickens from a nearby village were commonly seen searching for insects in the area surrounding the plots. Sweet potato weevil would have been vulnerable to attack by these and other natural enemies while searching for a suitable host.

Level of attack by Sweet Potato Weevil in relation to tuber formation, marketable yield and profit.

Sweet potato plants attract Sweet Potato Weevil by releasing chemical attractants during the formation of new tubers between 28 and 56 DAP (Wilson, 1982). Because sweet potato intercropped with both corn and soybean received less light than did the monoculture, tuber formation and the release of the chemical attractant were probably delayed, thus delaying movement of sweet potato weevil towards its host. Unfortunately, reduced light levels were probably also responsible for the lower number of tubers per plant, and the lower weight of fresh tubers per 10 plants, especially where sweet potato was intercropped with corn (Tables 4 & 5). Hahn (1977) found that a lack of light caused a decrease in the net assimilation rate and dry matter production, especially during the formation of tubers. Moreno (1982) found that intercropping sweet potato with corn in Guatemala reduced sweet potato yield by 63%; Roberts *et al.*, (1983) found that in Trinidad, yield reduction ranged from 10% to 44%.

In the present study, yield of fresh tubers was lower when sweet potato was intercropped with corn than with soybean (Table 5), presumably because of the greater shading effect of corn. Soybean may also have provided additional nitrogen to the sweet potato. This possible benefit, however, was not evident when sweet potato was intercropped with corn and soybean (D; Table 5), probably because of competition from the corn for limited resources, particularly light, nutrients, water and space. Thus, although number of both pest insects and damaged tubers were lower in intercropped treatments (Tables 2 & 3), marketable yield and profit were significantly reduced (Tables 4 & 5).

Because of the lower number of weevils in the corn + sweet potato mixture, intercropping with corn seems to be the most promising strategy for control of sweet potato weevil, and should be investigated further. However, the 40 to 70% reduction in economic value of marketable yield (Table 5) provides a considerable challenge to overcome. At present, sweet potato monoculture is likely to be preferred by farmers in Irian Jaya. Among the intercropping systems examined in the present study, the sweet potato + soybean mixture (C) was the best for increasing income and meeting nutritional requirements of the indigenous people in both the lowland and highland regions of Irian Jaya. The introduction of soybean into an indigenous sweet potato cropping system provides several advantages: (1) because soybean fixes nitrogen, it may increase the amount of nitrogen in the soil available to the sweet potato; (2) protein-rich soybeans would also enhance the nutritional quality of the indigenous diet. Unfortunately this value of soybean has not yet been recognized by Irian Jaya farmers, who still primarily regard soybean as a cash crop (La Ahmady, 1988); (3) the soybean crop may help the farmers diversify their production base by providing them with a second marketable commodity. The failure of one crop within an intercropping system as a result of adverse environmental conditions, such as drought, pests, or diseases, can be compensated for by the presence of other crops, thus providing yield stability (Kass, 1987).

CONCLUSIONS

In the present study, intercropping sweet potato with either corn and/or soybean was found to reduce the density of sweet potato weevil population, rate of colonization by sweet potato weevil, and the associated level of damage to the sweet potato tubers. Number of tubers per plant, yield and profit were higher, however, in the sweet potato monoculture.

Intercropping with corn was most effective from a pest management point of view, probably because it provided a more significant physical barrier to the movement of the sweet potato weevil than did the soybean plants. Moreover, by delaying tuber formation, it may have made the sweet potato plants less attractive to the sweet potato weevil. Unfortunately, this retardation of tuber formation also significantly reduced sweet potato yield, making intercropping unlikely to be used for weevil control by farmers in Irian Jaya.

Sweet potato intercropped with soybean yielded the second highest income after the sweet potato monoculture. Thus, further work with soybean may be warranted to find appropriate crop ratios and spacings that are both effective in controlling sweet potato weevil, and economically and culturally acceptable to local farmers. The present study comprises the first investigation into the use of intercropping for the control of sweet potato weevil (and any other insect pest) in Irian Jaya. Although the results are preliminary, they suggest further investigation in three areas: (1) a quantitative evaluation of the different mechanisms by which corn and soybean reduces damage by sweet potato weevil, e.g., physical barrier, chemical repellent, retardation of tuber formation, and provision of a suitable habitat for natural control organisms; (2) intercropping experiments with shorter cultivars of corn, shade tolerant sweet potato cultivars, different spacings between rows and different times of planting; and (3) testing of different cultivars to identify compatibility, with minimum competition and antagonism. However, such studies must take into account the nutritional and cultural implications of intercropping systems for local farmers. By building on indigenous knowledge and customs, and choosing cropping systems that are compatible with traditional methods of production, chances of adoption by indigenous people are likely to be increased.

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