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### The Ecological Role of Weeds in Insect Pest Management Systems: A Review Illustrated by Bean (*Phaseolus vulgaris*) Cropping Systems

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# The Ecological Role of Weeds in Insect Pest Management Systems: A Review Illustrated by Bean (*Phaseolus vulgaris*) Cropping Systems

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**Summary.** Weeds are major components of agro-ecosystems and they affect the biology of pests and beneficial insects in several ways; provision of flowers, presence of neutral insects, modification of crop microclimate, production of chemical stimulus, alteration of colonisation background, etc. The more relevant beneficial crop–weed–insect interactions are discussed. The role of weeds in regulating pest populations is illustrated by studies on bean (*Phaseolus vulgaris* L.) cropping systems, in which chemical interactions between *Empoasca kraemeri* Ross & Moore and two grass weeds were identified. It is proposed to continue and develop this kind of research in order to incorporate weeds into pest control strategies.

## Introduction

Throughout history man has focused his attention on the negative competitive effects of weeds and has concentrated his efforts on controlling them culturally and chemically, paying little attention to their beneficial role in determining diversity and stability of insect populations in agro-ecosystems.

This paper reviews the major beneficial effects of weeds on insect populations in agro-ecosystems and the potential usefulness of some of the more impressive interactions in pest management programmes. Table 1 shows some interactions that have been demonstrated experimentally.

## The entomological niche of weeds

Weeds are major components of agro-ecosystems, making a definite contribution to the richness of the fauna within these systems. For example, Goeden and Ricker (1975) have reported 87 insect species associated with *Ambrosia confertiflora* De Candolle in southern California, and Figueroa (1976) has reported 30 in association with *Amaranthus dubius* Mart. in Colombia.

Theoretically this greater diversity of insect species in weedy plots may increase community and insect stability within the crop area, mainly as a result of increased biological control, as discussed by Pimentel (1961), Root (1973), Smith and Van den Bosch (1967) and van Emden and Williams (1974). However, it seems that the correct functioning of this mechanism depends on the type of weed community, its aggressiveness and the associated entomofauna, particularly in relation to the organisation of trophic webs. Although weeds are often important pest hosts in agro-ecosystems (van Emden (1965) cites more than 400 pest problems caused by weeds), this aspect will not be discussed here. Thurston (1970), Heathcote (1970) and Tamaki *et al.* (1975) have reviewed this aspect extensively. However, weeds may have a number of other effects.

## Weeds as a source of flowers for beneficial insects

Van Emden (1965) has analysed in detail the role of weeds in the biology of pests and beneficial insects. Weeds are frequently the only source of flowers (pollen and nectar), which are vital in maintaining high populations of beneficial insects within an agro-ecosystem. He mentions syrphids and five other predator families as being favoured by weeds. Syme (1975) also mentions some parasites (mainly Ichneumonidae) that depend on weeds.

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TABLE 1. SOME BENEFICIAL CROP-WEED-INSECT INTERACTIONS

Weed	Crop	Pest regulated	Factor	Reference
<i>Rubus</i> sp.	Vineyards	<i>Plutella maculipennis</i> (Curt.)	Alternative host for <i>Horogenes</i> spp.	Van Emden and Williams, 1974
<i>Ambrosia artemisioides</i>	Cotton	<i>Heliothis</i> sp.	Predators	Smith and Reynolds, 1972
<i>Rumex crispus</i> L.	Cotton	<i>Heliothis</i> sp.	Predators	Smith and Reynolds, 1972
Weed complex [ <i>Barbarea vulgaris</i> R.Br. <i>Armoracia rusticans</i> Gaertn <i>Cardamine pennsylvanica</i> Muhl. <i>Lepidium campestre</i> (L.) R.Br. <i>Brassica nigra</i> (L.)]	Cabbage	Aphids [mainly <i>Brevicoryne brassicae</i> (L.)]	Predators and parasites	Pimentel, 1961
Weed complex (unidentified)	Citrus	Mites [ <i>Parlatoria pergandei</i> (Comstock) <i>Aonidiella citrina</i> (Comstock)] <i>Phyllotreta cruciferae</i> Goeze	Unknown	Muma, 1970
<i>Ambrosia artemisiifolia</i> De Candolle	Collards		Chemical interaction	Tahvanainen and Root, 1972
Weed complex (Unidentified)	Maize	<i>Prorachia daria</i> L. <i>Laphygma frugiperda</i> (J. E. Smith)	Unknown	Guevara, 1962
Weed complex ( <i>Avena fatua</i> L. <i>Polygonum persicaria</i> L. <i>P. aviculare</i> L. <i>Chenopodium album</i> L. <i>Sinapsis arvensis</i> L. <i>Solanum nigrum</i> L., etc.)	Brussel sprouts	<i>Brevicoryne brassicae</i> (L.) <i>Pieris rapae</i> (L.) <i>Erioischia brassicae</i> (L.)	Predators and parasites	Dempster and Coaker, 1974
Weed complex ( <i>Spergula arvensis</i> L. <i>Chenopodium album</i> L. <i>Polygonum persicaria</i> L. <i>Raphanus raphanistrum</i> L. <i>Sinapsis arvensis</i> L.)	Brussel sprouts	<i>Brevicoryne brassicae</i> (L.) <i>Myzus persicae</i> (Sulz.) <i>Aphis fabae</i> Scop. <i>Aleyrodes brassicae</i> (Wlk) <i>Mamestra brassicae</i> (L.) <i>Pieris rapae</i> (L.) <i>Pionea forticalis</i> (L.)	Biotic and light relations	
<i>Eleusine indica</i> (L.) Gaertn <i>Leptochloa filiformis</i> (Lam.) Beauv.	Beans	<i>Empoasca kraemeri</i> Ross and Moore	Chemical interactions	Herein reported
Wild blackberries ( <i>Rubus</i> sp.)	Vineyards	Grape leafhopper	Alternative host for <i>Anagrus epos</i> Girault	Smith and Van den Bosch, 1967
Weed complex (unidentified)	Mung beans	<i>Ophiomya phaseoli</i> (Tyron)	Unknown	Litsinger and Moody, 1975
<i>Sorghum halepense</i> (L.) Pers.	Vineyards	<i>Eotetranychus willamettei</i> Ewing	Alternative prey for predatory phytoseids	Flaherty, 1969

Perrin (1975) reports that *Urtica dioica* L. is a weed that provides alternative feeding sites for 11 different species of beneficial insects. In Colombia, Reyes (1976) stresses the importance of *Bidens pilosa* L. since this weed is often visited by nine parasites of *Diatraea* sp. and *Caligo illioneus* Cramer; he points out its potential usefulness in the integrated control of sugarcane pests.

Root (1973) says that weeds provide important requirements for natural enemies and that these organisms are more effective and abundant in weedy plots (complex environments), as was the case with coccinellids, syrphids and *Aphidoletes* sp. preying on aphids on cole plants (Pimentel, 1961); *Anthocoris nemorum* (L.), *Harpalus rufipes* Deg., spiders and syrphids preying on *Pieris rapae* (L.) on brussel sprouts (Dempster, 1969); and *Syrphus balteatus*, *Melanostoma* spp. and *Anthocoris nemorum* (L.) as predators of aphids on brussel sprouts (Smith, 1976b). Pollard (1971) and Fuchs and Harding (1976) support these results; they found more arthropod predators and syrphids in diversified than in simple habitats.

### *Weeds as a source of neutral insects*

Some weeds also maintain a certain level of neutral insects that may serve as alternative food for predators or parasites. Van Emden and Williams (1974) mention as an example *Horogenes* spp., an effective parasite of *Plutella maculipennis* (Curt.) in vineyards, that requires another prey to bridge an overwintering larval generation after the parasite emerges in the autumn. The alternative host is provided by a wild species of *Rubus*. The same kind of relationship is reported by Smith and van den Bosch (1967); wild blackberries provide alternate winter hosts for *Anagrus epos* Gir., an effective parasite of grape leafhoppers.

### *Physical barriers*

Hedgerows in crop areas act as windbreaks and may affect insect populations (van Emden, 1974). One way of diminishing the number of pests in crop systems is to shelter the crops with windbreaks so that insects that might otherwise be blown over the crops accumulate around the hedgerows (Lewis and Smith, 1969). The relationship, however, is complicated, because wind and wind interception may reduce flight activity and alter body temperatures, affecting pest incidence either favourably or adversely (Cloudsley-Thompson, 1962).

### *Modification of the crop microclimate*

There is no precise reference confirming the influence of specific weeds on the microclimate of a crop; nevertheless, Tahvanainen and Root (1972) state that complex environments — i.e., weedy agro-ecosystems — have a relatively complex external appearance and associated pattern of microclimates. Thus insects may experience further difficulty in finding a favourable microclimate because of the variety of abiotic factors in the many different microhabitats of the community.

Lewis (1965) gives some examples where shade may increase or decrease initial pest infestation. Cloudsley-Thompson (1962) has demonstrated that insects exhibit specific microclimatic preferences. He states clearly that organisms occupying the same general habitat may actually be living under very different physical conditions. The presence of weeds may ameliorate climatic conditions to a marked degree; not only plant height but also herbage quality and density may affect temperature and humidity.

### *Alteration of colonisation conditions*

Smith (1976a) found lower populations of *Brevicoryne brassicae* (L.) and six other important pests in wild cabbage (*Brassica oleracea* L.) ecosystems with a weedy background. These results led her to conclude that weed-free brussels sprouts crops provide ideal colonisation conditions for pests. This preference for plants growing on bare soil is partly due to the insect's phototactic reaction but more to the optomotor reaction caused by plants highlighted against a bare soil background. Similarly, Cromartie (1975) found that a vegetative background significantly decreased colonisation of collard plants by herbivorous insects, and it appears that many potential pest species preferentially colonise large, pure stands of their host plants.

Thorsteinson (1960) states that some phytophagous insects perceive shape and colour differences with considerable clarity. Although the spectral composition of light reflected from the surface of plants is relatively narrow in range, it seems that this aspect plays a critical role in the recognition of preferred food plants.

### *Chemical interactions*

The most striking example of this kind of interaction is the work of Tahvanainen and Root (1972), which shows a chemical interaction between *Phyllotreta cruciferae* Goeze and *Ambrosia artemisiifolia* De Candolle, benefiting *Brassica oleracea*. According to these authors, interplanting non-host plants can decrease colonisation efficiency and subsequent population density of pests drastically. In complex communities, the biotic, structural, chemical and microclimatic complexity of diverse communities results in an 'associational resistance' to specialised phytophagous insects, in addition to the resistance of individual plants.

The proximity of a non-host plant can greatly decrease the utilisation of collards by *P. cruciferae*; this interference is due to olfactory repulsion and/or a feeding inhibition. Thorsteinson (1960) states that odours are significant in food plant recognition during the final food-finding stage. Based on the electrophysiological studies of Dethier and Schoonhoven (1969), it can be concluded that a combination of chemical substances (and consequently odours) may cause severe antagonism and alteration of colonisation, reproduction and feeding efficiency of phytophagous insects.

### Some crop–weed–insect interactions in tropical agro-ecosystems

Holdridge (1959) and Janzen (1973) define tropical agro-ecosystems as diversified systems with assemblages of crops in polycultural patterns. In Latin America, for example, 60% of the maize and 80% of the beans are grown intercropped (Francis *et al.*, 1975). At the commercial level, however, crops such as cotton and sugarcane are cultivated extensively as monocultures.

Many ecologists suggest that a more rational cropping system for the tropics is achieved when the functional and structural characteristics of a diversified tropical ecosystem, e.g., tropical rainforest, are stimulated. In such a system, weeds are an important element; Garcia *et al.* (1975) present more than 277 common tropical weed species in their catalogue, thus illustrating the diversity and complexity of weed communities in the tropics.

### Study of crop–weed–insect interactions in the Colombian tropics

In an attempt to determine the major crop-weed-insect interactions in a bean cropping system in the Colombian tropics, four field experiments were conducted at the Centro Internacional de Agricultura Tropical (CIAT), located in the Valle del Cauca, Palmira. General experimental conditions were as follows: altitude 1000 m, mean annual rainfall 1000 mm, two wet and two dry seasons per year, and a mean annual temperature of 24°C. The most common pests of beans are *Empoasca kraemeri* (Homoptera: Cicadellidae) and chrysomelids, of which *Diabrotica balteata* Le Conte is the principal species. There are sporadic attacks of mites and cutworms, but they were not considered in the present studies.

#### *Bean (Phaseolus vulgaris) monocultures diversified with five different weed densities*

Each plot measured 80 m<sup>2</sup>, and a randomised block design with three replications was used. Beans were planted at a commercial density of 160,000/ha. The weed densities consisted of 0, 25, 50, 75 and 100% soil cover. The 0% weed level (weed-free monoculture) was obtained with pre-emergence herbicide treatments; the four other

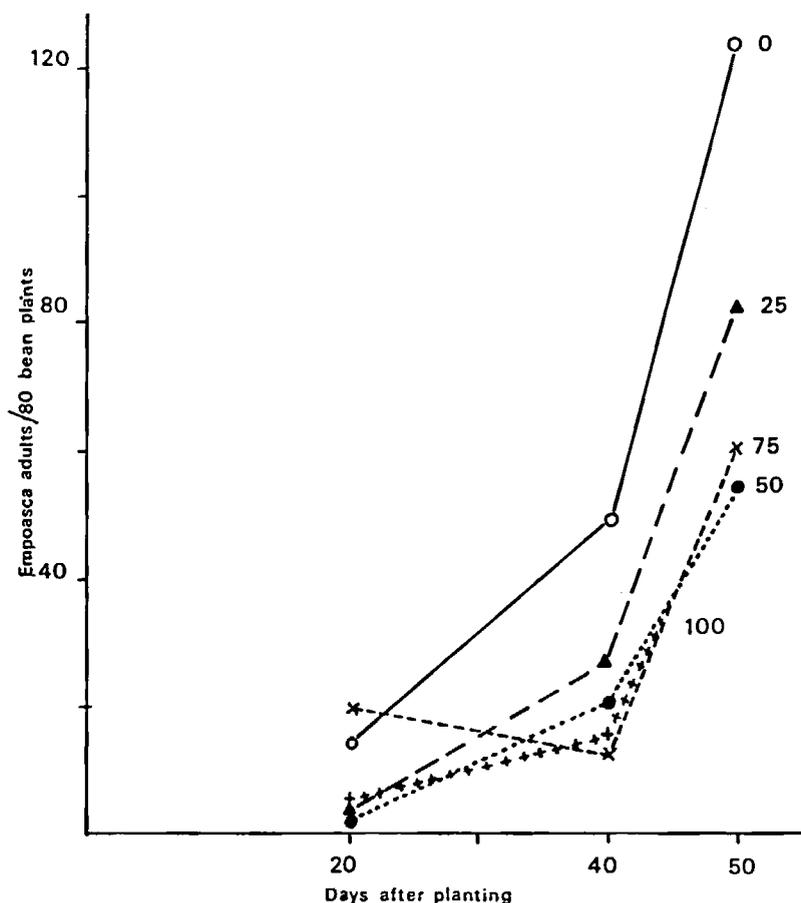


Fig. 1. Effect of five weed densities (0–100% soil cover) on the mean adult population of *Empoasca kraemeri* on beans.

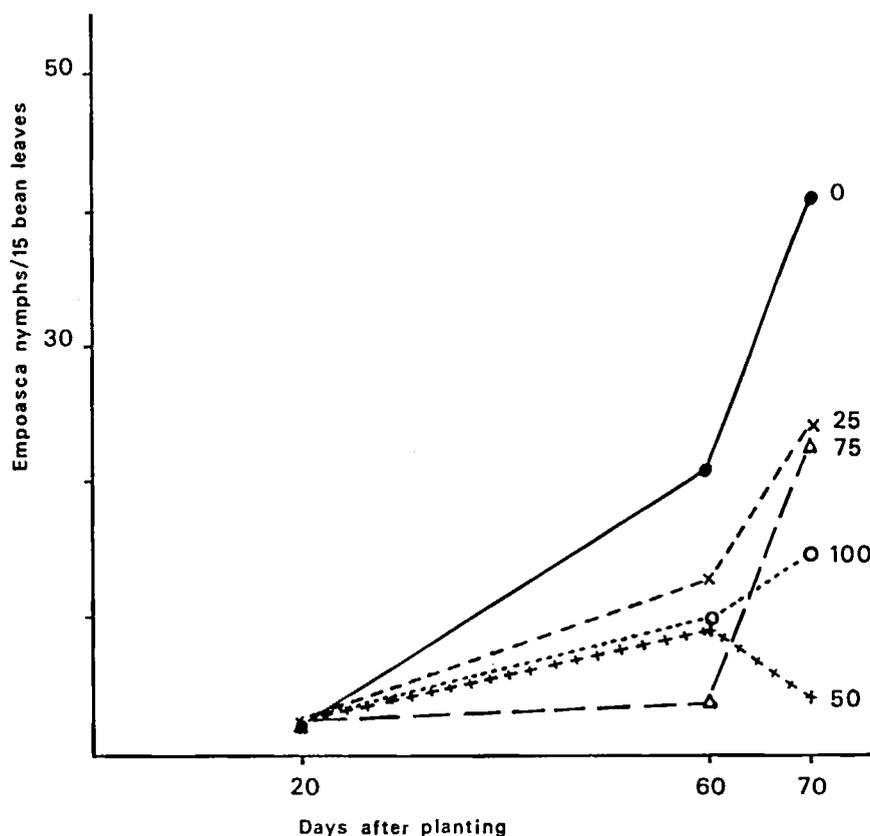


Fig. 2. Effect of five weed densities (0–100% soil cover) on the mean nymph population of *Empoasca kraemeri* on beans.

densities were obtained with differential seeding of weed mixtures (1–4 l weed seeds/720 m<sup>2</sup>) of *Eleusine indica* (L.) Gaertn, *Leptochloa filiformis* (Lam.) Beauv., *Digitaria sanguinalis* (L.) Scop., *Amaranthus dubius* Mart., *Ipomoea* sp. and *Euphorbia* sp. Twenty days after planting, these densities were corrected by differential hoeing. Insect populations were sampled with a D-Vac sampler every ten days.

Under these tropical and experimental conditions, adult and nymph populations of *Empoasca kraemeri*, the main bean pest of the Latin American tropics, were significantly higher in weed-free bean monocultures than in beans diversified with weeds (Figs. 1 and 2).

The predator population consisted mainly of *Condylostylus* sp. (Diptera: Dolichopodidae), Reduviidae and Nabidae, but their populations were not high in any system (Table 2). *Condylostylus* sp. density was not affected significantly by habitat diversity, hemipterous predators showed a slight increase in numbers with weediness.

TABLE 2. INCIDENCE OF PESTS AND PREDATORS IN DIFFERENT BEAN-WEED SYSTEMS

% soil covered with weeds	<i>E. kraemeri</i>		<i>D. balteata</i>	Dolichopodidae	Reduviidae and Nabidae
	Adults/80 bean plants	Nymphs/15 bean leaves	adults/80 bean plants	adults/80 bean plants	adults/80 bean plants
0	52.8 c*	22.4 b	2.3	0.98	1.48
25	37.7 b	13.8 a	3.6	0.60	2.60
50	29.7 a	10.5 a	6.7	1.40	2.60
75	28.4 a	11.8 a	5.6	0.95	3.30
100	30.1 a	6.7 a	4.5	0.83	3.70
				N.S.	N.S.

\* Numbers followed by same letter in each column do not differ significantly (5% level).

The main parasite of *E. kraemeri*, *Anagrus* sp. (Hymenoptera: Mymaridae) showed little difference in activity in the different habitats, with 57% egg parasitism in the weed-free bean monoculture and an average of 54% in the weed diversified bean habitats, as measured by percentage of parasites over number of nymphs emerged.

These results differ from those of Pimentel (1961) who observed greater predator and parasite activity in monocultures resulting from higher pest populations and immigration of natural enemies from diversified plots. The similarity in abundance of natural enemies we observed in the different bean systems and the difference in pest population might suggest that monoculture enhanced the activity and efficiency of the farmer. However it is believed that size and proximity of plots were the two main factors involved, and that natural enemies were not entirely responsible for the differences found in *E. kraemeri* populations. This is in agreement with the findings of Tahvanainen and Root (1972).

TABLE 3. BEAN DAMAGE AND YIELDS IN DIFFERENT BEAN-WEED SYSTEMS

% of soil covered by weeds	Damage by <i>D. balteata</i> (holes/15 bean leaves)	Bean yield (tons/ha)
0	24 a	1.70
25	30 a	1.78
50	40 b	1.75
75	41 b	1.79
100	41 b	1.85
		N.S.

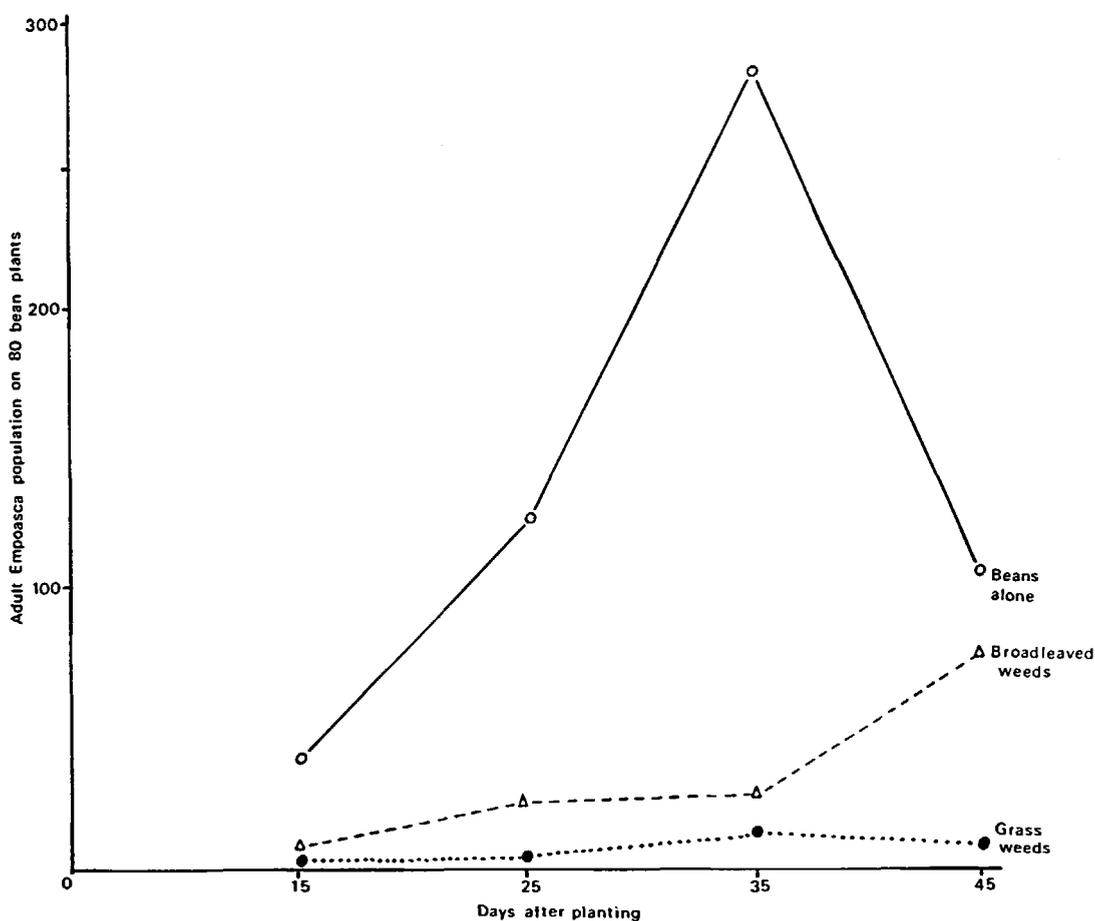


Fig. 3. Effect of weed type (broadleaved and grass weeds) on the population of adult *Empoasca kraemeri* on beans.

*Diabrotica balteata* (Coleoptera: Chrysomelidae), another common bean pest, responded quite differently, showing larger populations in diversified habitats than in bean monocultures, which was reflected in the level of damage (Table 3).

This insect is highly polyphagous and it is assumed that weed diversity and biomass were responsible for the larger numbers in weedy habitats. Although *D. balteata* fed more extensively in diversified habitats, bean production was not affected because polyphagy on weeds somehow dilutes injury to beans. Bean yields were higher, but not significantly so, in weedy systems than in weed-free monocultures (Table 3), suggesting that the beneficial effect of weeds in reducing pest incidence compensates for the negative effect of weed competition. It should be emphasised that *E. kraemeri* and other pests probably could have reached higher populations in weed-free bean monocultures; however, this did not happen, presumably because of the proximity (less than 2 m) of weedy plots. This fact should be taken into account in future experiments where plot size and distance between treatments should be increased.

#### *Beans in broadleaved and grass weed associations*

To determine the principal weeds responsible for the differences in *E. kraemeri* populations between habitats, the following field experiment with three replications was conducted; a weed-free bean monoculture, a bean monoculture diversified with grass weeds, and beans diversified with broadleaved weeds. Each plot measured 6 m<sup>2</sup>, and the composition of the weed community was established by hoeing (weed-free system) and selective hand weeding (weedy systems). Beans were planted after the weed community had become established.

*E. kraemeri* populations were significantly reduced in weedy habitats, especially in grass weed (*Eleusine indica* and *Leptochloa filiformis*) habitats (Fig. 3). *D. balteata* showed a similar but less marked response; the presence of broadleaved weeds increased the population by 27% while grass weeds reduced it by 19%.

#### *Beans with grass weed borders*

To substantiate these results, another field experiment was conducted, in which grass weed borders one metre wide surrounded the bean monocultures. *Eleusine indica* and *Leptochloa filiformis* were the dominant grass weeds

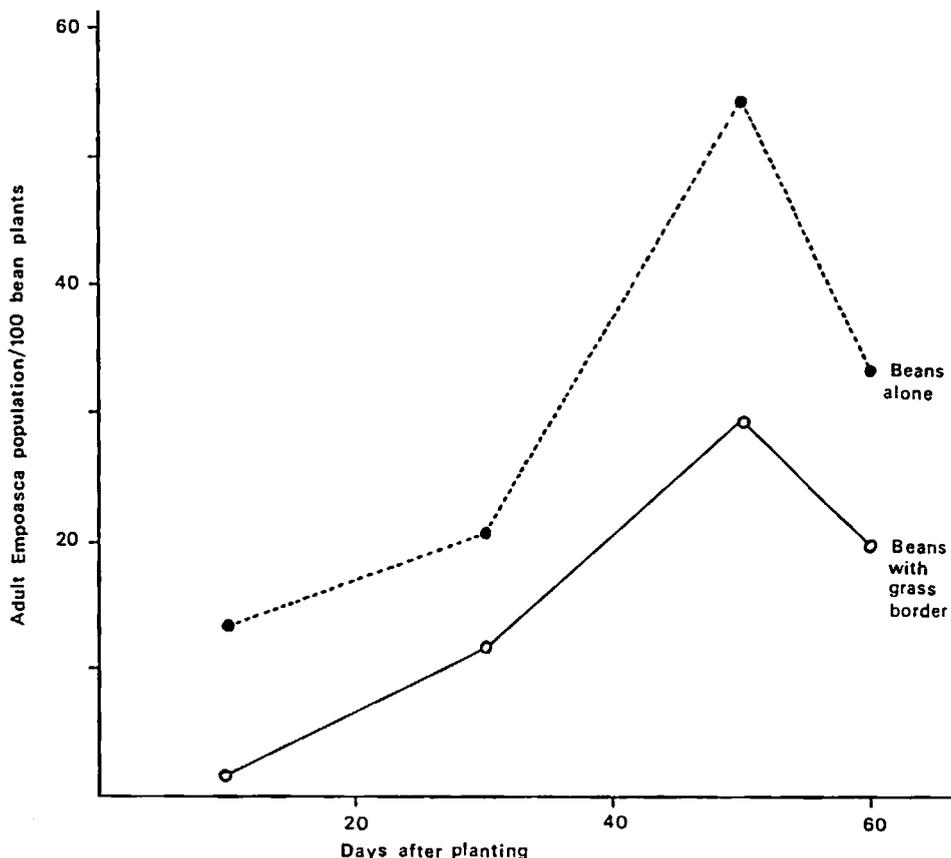


Fig. 4. Effect of the grass borders around 16 m<sup>2</sup> bean plots on the population of adult *Empoasca kraemeri*.

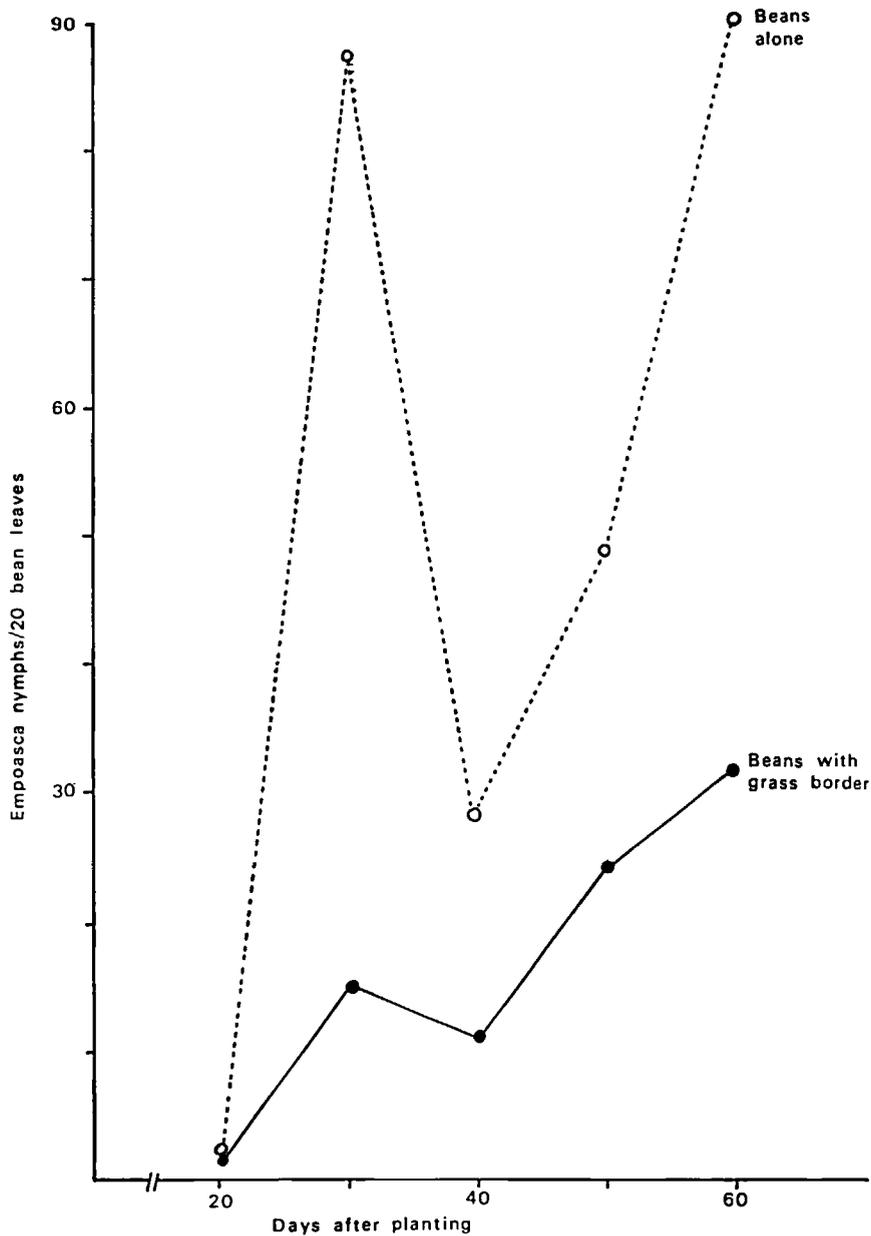


Fig. 5. Effect of the grass borders around 16 m<sup>2</sup> bean plots on the population of *Empoasca kraemeri* nymphs.

in the previous trials so they were selected as components of these borders, and seeded artificially around plots of 16 m<sup>2</sup>. Beans were planted after the borders were well established.

Figs. 4 and 5 give the population dynamics of *E. kraemeri* adults and nymphs; again, the regulatory effect of grass weeds stands out. It must be stated that these weeds neither provided a suitable habitat for natural enemies of *E. kraemeri* (no Dolichopodidae or Hemiptera were found in samples obtained from the borders) nor acted as trap plants, (an average of seven *E. kraemeri* adults were observed on 31 grass weed plants). The effect of these borders as physical barriers of leafhopper colonisation flight could not be demonstrated.

Future experiments will be aimed at determining the distances these effects extend and how they are regulated in order to develop alternative cropping systems such as strip cropping. It is also recommended that commercial grasses producing the same effect should be selected.

Bean yields in both systems were low because of lack of rainfall, soil fertilization and fungicidal treatments, but the grass border system gave a higher (0.65 tons/ha), although not significantly higher, yield than the weed-free system (0.55 tons/ha).

TABLE 4. AVERAGE PREFERENCE RATIO OF *E. KRAEMERI* ON BEANS AND BEANS + GRASS WEEDS IN A FREE CHOICE CHAMBER (AVERAGE OF 4 EXPERIMENTS)

Time after infestation (h)	No. of adults in chamber with bean leaves	No. of adults in chamber with bean + grass leaves
1	5.2 a	2.0 b
2	4.7 a	1.7 b
3	5.2 a	1.7 b
24	4.7 a	1.3 b
Mean	4.95 a	1.67 b

Laboratory observations showed that there was a chemical interaction between *E. kraemeri* and grass weeds. A choice chamber similar to that designed by Tahvanainen and Root (1972) was used, in which the preferences of *E. kraemeri* adults were tested on one bean leaf alone and one bean leaf plus three *E. indica* or *L. filiformis* leaves. The average preference ratio is given in Table 4. Based on these results, it can be stated that the average preference ratio of *E. kraemeri* is close to 5:1 towards bean leaves alone, indicating a repellent effect of the grass weeds tested. However, generalisations cannot be made for natural conditions because other factors may be involved.

#### Spraying weed solutions on bean plants

In order to find further evidence of chemical repellence, another field experiment was conducted in small plots (40 plants) of beans that were sprayed continuously with weed solutions. Thirty grammes of fresh weed leaves (*E. indica* and *L. filiformis*) were homogenised in a blender with 3 l of water and immediately sprayed on the bean plants with a small garden sprayer. The beans were sprayed six times and the experiment was replicated three times. *E. kraemeri* adult populations were sampled with a net passed 16 times/40 bean plants 1, 3, 6 and 24 hours after spraying. Table 5 shows the repellent effect exerted by these solutions. Water spraying had a disruptive effect on leafhopper populations, which suggests the potential of sprinkler irrigation for the control of *E. kraemeri*. It was also observed that these continuous applications of weed solutions affected reproduction of *E. kraemeri* and bean yields (Table 6).

In another greenhouse experiment, it was observed that these weeds interfere with the reproduction of *E. kraemeri*. When three bean plants infested with 100 adults were placed in a cage with four *Eleusine* or four *Leptochloa* plants, there were 47 nymphs/3 bean plants in the control cage and 12 and 6 nymphs in the *Eleusine* and *Leptochloa* cages respectively, 40 days afterwards (average of three replications repeated three times at 40 days after planting).

#### Discussion and conclusions

The results of these experiments suggest that the decreased colonisation and reproductive efficiency of *E. kraemeri* observed in grass weed-bean habitats were caused by repellent or masking chemical stimuli from *Eleusine indica* and *Leptochloa filiformis*. In the Colombian tropics, these weeds are common in bean agro-ecosystems

TABLE 5. THE EFFECT OF WEED SOLUTION SPRAYING ON *E. KRAEMERI* POPULATIONS ON BEANS (AVERAGE OF 6 OBSERVATIONS AT DIFFERENT TIMES)

Treatments	<i>Adults/40 bean plants</i>				Average $\bar{x}$
	1 h	3 h	6 h	24 h	
<i>E. indica</i>	4.3	1.6	0.6	13	4.9 a
<i>L. filiformis</i>	3.3	3.0	1.6	14	5.5 a
Water	6.0	3.3	1.3	14	6.2 a
Control	22.0	10.6	15.3	16.3	16.1 b

TABLE 6. EFFECT OF CONTINUOUS WEED SOLUTION APPLICATIONS ON *E. KRAEMERI* REPRODUCTION AND BEAN YIELDS

Treatment	No. of nymphs/ 10 leaves (60 days after planting)	Bean yields (tons/ha)
<i>E. indica</i>	14.6	0.86
<i>L. filiformis</i>	11.3	0.81
Water	19.3	0.79
Control	23.6	0.65
		N.S.

and easy to cultivate so that it would be possible to incorporate them in pest management programmes. Future developments in tropical bean pest management might consider the integration of these and other ecological strategies with the use of genetically resistant varieties.

These results and the examples reviewed suggest a great potential of weeds as biological components of some pest management systems. This idea has also been expressed by Smith (1976a). However, van Emden and Williams (1974) suggest that any beneficial contribution of weeds in pest problems never completely compensates for their competitive effect. This a controversial point because, as Bantilan *et al.* (1974) mention, the result will depend on the management of the crop-weed balance in favour of the crop. A considerable amount of work is now being done on the factors (climatic, edaphic, biological and cultural management) which influence this balance.

Crop-weed coexistence frequently occurs in agro-ecosystems, and in many cases higher crop yields have been obtained from weedy plots than those treated with herbicides. At CIAT, for example, high bean yields (1.8 tons/ha) have been obtained in systems diversified with weeds as a result of cultural management of the weed community. In this case intra- and interspecific competition between artificially seeded weeds delayed their germination and gave beans an initial advantage. In addition, the cutting of weed foliage to the same height as the bean plants, reduced competition for light. Similarly, Smith (1976a) allowed weeds to grow in a sprout crop but she cut them back regularly to about 15 cm high and removed weeds growing immediately beneath crop plants, so diminishing weed competition and thus obtaining satisfactory yields. Other strategies that attempt to reduce weed interference include providing weeds as borders or as alternate rows within the crop. Strip cropping with useful weeds would be another promising alternative. Planting beans between sugarcane just after cutting might prove to be a useful strategy.

Weed competition experiments make it clear that uncontrolled weed growth cannot be recommended (Kasasian and Seeyave, 1969; Doll, 1975), but it is the degree and type of control that has been discussed here. According to Way (1971), what is needed is to develop a strategy based on selective herbicides so that the less competitive weed species with beneficial effects on the crop are maintained while the aggressive species such as *Cyperus rotundus* L., *Rottboellia exaltata* L.F. and *Ipomoea* sp. in the tropics are eliminated.

It is hoped that further research will be conducted along these lines so that these ideas can be put into practice.

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