Indian J. Plant Prot. 27(1&2) : 87-108, 1999
ISSN 0253-4355

Cultural Practices in Insect Management with Reference to Groundnut

G.V. Ranga Rao and T.G. Shanower
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India.

Abstract

Cultural operations in agriculture have well established history about their role in insect pest population management. Various cultural practices directly or indirectly are known to contribute to the insect pest control. There have been several case studies documenting their positive role as pest reducers, however quantification of their indirect effects though significant, are difficult to substantiate. Global dependence on chemical control in the past two-three decades has contributed to the reduction of hunger to some extent, though the continuous dependence created several problems to natural resources. The awareness of the deleterious effects of chemicals led to the thinking about alternatives to chemicals. Over years we learnt how to grow high yields and now it is time to learn how to stabilize the food production with minimum effect on natural resources. In this process of thinking the role of cultural operations, with its interactions with all other control options gets high priority. In this paper we attempt to review the present status of cultural operations worldwide with some successful examples, using groundnut as a case study.

Introduction

Global plant protection in the past two decades has mainly concentrated on chemical control. Though there are successful cases of non chemical plant protection, their implementation has been inconsistent. The primary cause for the total dependence on chemicals was due to the need for increased food production to meet the demand of the growing world population. During this process the importance of improved technology including, chemical fertilizers, hybrids, insecticides and fungicides has become well known. The results from this phase were excellent and several countries achieved self sufficiency in food grains. Though this approach brought stability in food production across the world, it has several disadvantages. Total shift from organic farming to a high dependence of chemicals over long period contributed to a severe decline in soil fertility, and lowering trend of crop yields. The excessive use of insecticides destroyed the natural enemies like parasites and predators of the crop pest, resulted in the development of resistance in some species to different chemicals, secondary pest out breaks and the degradation in the quality of environment. Eventually lesser and lesser control of the crop pest became evident. To compensate this farmers started using more and more chemicals which worked for some time though temporarily. Considering all these disadvantages to come out of the chemical treadmill one has to look into alteratives to improve and stabilize agroecosystems. Among various alternatives natural products, biocontrol agents, sensible cropping systems, effective cultural operations and the wise use of chemicals are all important. Subsistence farmers with little resources must rely on natural pest regulation such as cultural controls. Several cultural practices employed under different agrosystems have profound influence on the insects and their natural enemies either directly or indirectly which either increase or decrease the crop stress from pests. Sometimes even slight population reduction brought about by these practices delays the build up of insect number which consequently reduce the plant damage. Although these methods are simple and easy to follow, they are subjected to variability of agroecological zones. In this paper we discuss the importance of cultural control in insect management with some successful ex-

amples from studies in groundnut production systems.

Field Sanitation

Practices such as removal or destruction of stubbles and stalks of crops can be highly effective in reducing the insect populations. Seshu Reddy (1990) suggested chopping sorghum and maize stalks and storing them as small pieces or destroying the stubbles and left-over stalks just before ploughing for next crop. This inhibits the initial infestation in the newly planted crop and allows successful crop establishment.

Verma and Singh (1989) discussed the role of some commonly adopted cultural practices and post harvest operations contributing towards reducing the carryover population buildup of sorghum stem borers. Kfir (1990) while explaining the prospects of cultural control in the management of *Chilo partellus* and *Busseola fusca* indicated about 70% population reduction by slashing the plants. Ploughing and disoing the plant residues reduced the population further by 24% in grain sorghum and 19% in maize in Pretoria, South Africa.

Cotton stalk destruction after harvest is a common practice in the Rio Grand Valley, Texas, to minimize damage by the cotton Boll Weevil *Anthonomus grandis* without the use of chemicals. Consistent application of this practice substantially reduced the pest as well as insecticidal use in that area thus minimized the environmental hazards.

Liquido (1993) in Hawaii showed the relative density of tephritid to be lower in clean orchards than in orchards with ripe and fallen fruit. The removal of ripened fruits from trees and ground twice a week helped in lowering the damage by *Dacus dorsalis* in papaya orchards in Hawaii. The orchards without sanitation had an irregular harvesting pattern which resulted in abundant ripe fruits on the trees and fallen rotting fruits on the ground. Mature green fruits had no infestation and the infestation was observed only in half-ripe and fully-ripe fruits.

Shanower *et al* (1993) reported oviposition by *Helicoverpa armigera* on exotic and typical substrates in chick-pea fields in Andhra Pradesh, India. Since eggs are laid on thin metal stakes bearing labels, weeds and stubble from previous cereal crops, it is suggested that large infestation on chickpea occurred due to the larval movement from weeds and other substrates onto chickpea plants. Hence field sanitation is important in minimizing the availability of alternative oviposition sites.

Schaber *et al* (1993) examined the effects of burning alfalfa stubbles for pest control. Plots burned during autumn had significantly higher yields compared to fields burnt before spring growth in Alberta, Canada. Field burning in autumn or spring before the crop growth increased the gross economic returns, however the insecticidal treatments gave the highest returns.

Dubois *et al* (1993) from Germany indicated that effective weeding in sugar beet field can reduce the spread of yellow mosaic virus by 33% by controlling the aphid vector. The carabid population antagonist to aphids showed good establishment where band application of herbicide was used rather than total application of herbicide. Thus integration of herbicide application to take advantage of natural enemy has been suggested to reduce the spread of yellow virus in sugar beet. Burning birdsfoot trefoil grown for seed reduced the number of mirids and increased the parasite activity in Wisconsin, USA (Peterson *et al* 1992).

Chamberlin *et al* (1993) showed that discing during November and February greatly reduced the density of volunteer groundnut and winter annual weeds but did not measurably decreased the abundance of brachypterous *Frankliniella fusca* in Georgia, USA. Post harvest tillage and carbofuran application did not measurably reduce the incidence of *F.fusca*, and the

transmission of tomato spotted wilt virus in the subsequent groundnut crop.

Preliminary studies conducted by Ranga Rao during 1995-96 in Vietnam groundnut fields indicated field burning after rice harvest had profound influence on the spider population. There was three fold difference in spider population between unsprayed and burnt fields, and 3 fold difference between sprayed and burnt situations (Table 1a) (Ranga Rao, 1996).

Chaudhary *et al* (1993) showed 47% reduction in the carry over population of peach borer by mild pruning and burning while the population was 36% lower by only pruning. Severe pruning resulted in 61% reduction in the pest population in Punjab, India. Integration of severe pruning of infested branches, followed by their destruction and application of balanced fertilizer in January and application of three sprayings with lindane at the time of adult emergence in April, June and September effectively managed the pest.

Soil solarization for 30 and 50 days reduced the incidence of *Verticillium* wilt in tomatoes and had a residual effect on the disease levels of eggplants transplanted in the same field 45 days after the tomato harvest in Sao Paulo, Brazil

Table 1a : Effect of different farm operations on Spider populations in groundnut during Winter/Spring 1995/96 in Vietnam.

Treatment	Mean number of spiders in meter row of groundnut
Sprayed	0.12
Unsprayed	0.39
Burnt Field after Rice	0.04
SE	±0.06

Sprayed fields were treated with insecticides twice.
There was 10 fold difference in spider activity between unsprayed and burnt fields.
3 fold difference in population between sprayed and burnt fields.

(Ghini *et al* 1993). However there was no correlation between the low disease level and the increase in yield for either crop. The weed community was also affected by solarization. Solarization and treatment with methyl bromide considerably reduced the populations of several groups of mites and insects but these populations regained pre-treatment levels in 11.5 months.

Studies conducted in Thailand on the influence of shoot thinning of bamboo shoot borer, aphid and dried-disease indicate no reduction of shoot borer population with different levels of thinning, however thinning was associated with higher level of *Fusarium* (Choldumrongkul and Atirattanapunya 1993).

Gahukar (1991) indicated regular intensive weeding and planting as early as feasible were potentially useful options for the management of blister beetles in African food crops. Studies from Cameroon on pruning cotton plants resulted in 45% reduction in the aphid population. (Ekukole 1990).

Tillage

Soil tillage may reduce insect populations through mechanical damage, by disturbing their biological rhythm either by burying them so deeply that they cannot emerge, or by bringing them to the surface where they are exposed to adverse weather conditions, such as high and low temperatures, birds and other natural enemies. Some insects are vulnerable to the change in soil texture as a result of cultivation, where as such changes may favor other species. Tillage after the crop harvest and before planting destroy habitats such as stubbles, weeds and other alternate hosts which may provide shelter to pest insects.

Yadav (1981) indicated that deep ploughing reduces the whitegrub populations. This reduction is mostly achieved by exposing the diapausing grubs to the harsh environmental conditions and predation by birds. With the introduction of farm machinery it is possible to plough

during cool nights, where the exposure of insect populations to natural enemies is not possible. Farmers in Nigeria controlled termites by rolling drums, introducing soldier ants into termite nests and burying animal and plant debris in the fields (Malaka, 1972).

Hudon and Khanizadeh (1993) suggested the usual conventional ploughing in autumn and discing in the spring as the most efficient and economical methods for reducing the univoltine over-wintering larvae of *Ostrinia nubilalis* by 75% in Street corn fields in Quebec, Canada. However they have concluded that these operations must be practised over large areas to be most effective.

Field tests in Georgia demonstrated reduced infestation of *Spodoptera frugiperda* in seedling maize associated with no-till as compared with plough-tillage. This reduced one application of chlorpyriphos (Roberts and All 1993).

Zero tillage and rich straw mulch suppressed the population of leaf hopper *Empoasca ricei*, long horned grasshopper, *Phaneroptera furcifera* and to a certain extent beanfly *Ophiomyia phaseoli* in Soybean in Philippines. Plant density adversely affected the population of *E. ricei* and leaf folders *Homona coffearia* and *Lamprosema indicata*. It was hypothesised that the thickness of the canopy of higher plant densities created humid and shaded micro-environment which favoured the leaf hopper and leaf folder development.

Results from northeastern USA indicated that reduced tillage, side application of nitrogen, and early planting of corn reduce the incidence and damage levels of western corn rootworm, *Diabrotica virgifera virgifera Leconte*. (Roth *et al* 1995).

Mack and Backman (1990) from USA found twice the population of lesser cornstalk borer *Elasmopalpus lignosellus* in late planted (Late May) peanut fields as compared to early planting. The abundance of Labidurid was unaffected by planting date. Tillage system had no affect on the abundance of insect pests.

Plant Nutrition

Plant nutrition is an important factor in determining a plant's resistance or susceptibility to any biotic constraint. The relative availability may influence the reaction of plant to an insect pest. It has been established that fertilizers enhance plant nutrition and this often influences the basic biology and damage potential of insects. In Indonesia, application of potassium decreased the damage of sugarcane borer (Hatmosoewarno, 1970). The increased application of potassium in rice resulted in altering the balance of the aminoacids thereby effecting the development of stemborers in India. (Vaithilingam and Balasubramanian, 1978).

Letourneau (1993) showed that soil nitrogen was positively correlated with most common species of bean flies and soil phosphorus was negatively correlated with the population densities of two species *Ophiomyia spencerella* and *O. phaseoli*. In addition to the plant nutrition she also showed that straw mulching in newly sown fields may reduce the damage by the agromyzids in phaseolus beans in Malawi.

Higher soil levels of P and K increased seed yields of soybean, though the populations of velvetbean caterpillar were also increased with higher P. The populations of southern green stink bug were not affected by K or Mg in south eastern USA. (Funderburk *et al* 1991).

Planting time and Spatial Arrangement

Adjusting the time of planting often helps crops to escape the vulnerable phase of an insect pest. However, in semi-arid zones, where rainfall is unpredictable, the early sown crops always gets benefited from the physiological and ecological changes that occur during the crop phase. In same cases though the delayed sowings escape the insects, yields are not up to the expectations.

Therefore adjustment of planting dates in rainfed agriculture in semi-arid regions needs critical data base to make planting decisions.

The influence of planting date on the seasonal abundance of tobacco budworm and aphid in flue cured tobacco in Georgia indicated yearly effects rather than clear cut trends. Planting date influenced the aphid populations in only one year out of three years when higher populations were observed, however the effect of planting dates on the noctuid population was distinct in two of the three years (Mc Pherson *et al* 1993).

Ali (1993) studied the effects of cultural operations in reducing the infestation of potato tuber moth (*Phthorimea operculella*) and greening of potatoes in Sudan and found planting in the 2nd week of November had less insect damage and significantly increased yields compared to crops planted three weeks later. Greater depth of planting and more frequent hilling-up also reduced the infestation and reduced the greening of tubers. Irrigation and mulching also reduced the infestation and tuber greening, thus he suggested light irrigation every 4 days and mulching with neem leaves during the last 4 weeks before harvest.

Begum *et al* (1992) studied the effect of sowing time and plant density on pod damage by *Helicoverpa armigera* in chickpea crops in Bangladesh. They found infestation levels affected by sowing date and plant density. The yield was affected by variety and plant density. Although the late sown chickpeas at high plant densities were damaged most by *H. armigera*, the yields were higher than the early sown crops.

Cotton planted in Turkey was unaffected by the slight development of white flies, but as planting time delayed the plants became more sensitive to the infestation which resulted in reduced yields. Different row spacings (120, 100 and 80 cm) affected plant growth and development of alerodid populations. Whitefly populations decreased with increased row spacing. Closer spacing provided better habitat to *B. tabaci* with good canopy cover (Isler and Ozgur 1992).

The early sown (15th October) mustard crop in Madhya Pradesh, had less incidence of aphids and gave higher yields as the aphids appeared 74-76 days after sowing. The results demonstrated that every 10 day delay in sowing resulted in an increase of 36 aphids/5cm apical shoot and a reduction of 93kg ha^{-1} in grain yield. (Bhadauria *et al* 1992).

Singla *et al* (1991) from Punjab, indicated that larval population of *H.armigera* and its damage decreased with increased plant spacing in chickpea crop. The net return was highest at spacing of 10 and 15cm and was similar to normal spaced plants protected with endosulfan.

Early planting need is not always advantageous, sometime like in triticale in Georgia early planting (October) enhanced the autumn and winter infestation by Hessian fly. Late planting (December) avoided the autumn infestation (Zelarayan *et al* 1991)

Slosser *et al* (1992) from Texas showed that aphid population increased rapidly during August each year in June planted cotton, which suggests that sowing time interacts with plant age to influence insect population development. They had also shown that aphid number were positively associated with leaf nitrogen and leaf moisture, and the association was negative for whiteflies.

Studies conducted in Haryana, India, indicated plant density per unit area inversely affected the population of *Amrasca biguttula*. However the largest *Leucinodes orbanalis* infestation was observed at the greatest plant density in eggplants (Chaudhary and Kashyap 1992).

Intercropping

Intercropping is the most common cultural practice in many areas, especially in traditional agricultural systems. Intercropping modifies the crop

micro environment which influences the infestation, development and spread of insect pests and their natural enemies. The principle of controlling insect pest through intercropping by creating the diverse environment has been discussed by several scientists. Madhavan and Chellaiah (1986) from India reported 9% stemborer damage in sorghum intercropped with Lab compared to 33% in sole crop. Similarly Chand and Sharma (1977) found lower stemborer damage in maize grown in association with various legumes. Thus it is clear that intercropping with non-host crops can bring about a considerable reduction in pest population on main crop.

Studies conducted by Kumar and co-workers (1992) from India on the effects of intercropping of pigeonpea with blackgram (*Vigna mungo*) on the incidence of *Helicoverpa armigera* and *Melanagromyza obstusa* suggested that intercropping was an effective tool in controlling both the pest species. The level of control was as effective as in the insecticidal application. They have suggested growing 4.5-9.0m pigeonpea with 2.1-2.4m bands of blackgram.

Wiech and Wnuk (1991) showed that the number of carabids increased by 32% when the cabbage was grown with *Trifolium repens* in Poland. The population of aphids was less under intercropping situation as compared to monoculture.

Studies conducted in Shimoga, India showed castor to be an effective trap crop in tobacco fields. *Spodoptera* adults preferred castor for oviposition site in tobacco fields. There was 7% leaf damage in IPM plots compared to 11% in insecticidal plots and 31% in control plots (Shivayogeswara *et al.* 1991.)

Dissemond and Hindorf (1990) reported the reduction of *Chilo partellus, Busseola fusca, Eldana saccharina* and *Sesamia calamistis* populations with intercropping sorghum / maize / cowpea in Kenya.

Studies conducted by Varun and others (1994) in Uttar Pradesh, India indicated intercropping sugarcane with spices such as coriander, onion, garlic, menthi (Fenugreek), snauf (*Foeniculam vulgare*), mangrail (*Nigella sativa*), and Ajawain (*Trachyspermum copticum*) reduced the incidence of *Chilo infescatellus* from 9% to 3%.

Field trails conducted at Bangalore, India showed that the cabbage pests *Plutella xylostella, Crocidolomia binotalis, Helicoverpa armigera, Brevicoryne brassicae* and *Lipaphis erysimi* preferred mustard to cabbage when choice was available. Srinivasan *et al* (1991) suggested 9 rows of cabbage and one paired row of mustard.

Intercropping reduced the number of *Megalurothhrips sjostedti, Clavigralla tomentosicollis* and *Riportus dentipes*, but made no difference to number of *Maruca testulalis* in cowpeas. Unprotected cowpea alone and intercropped cowpea had yields reduced by 55 and 48% respectively compared to plots protected with insecticides in Nigeria (Alghali 1993).

Growing one row of *Tagitus erecta* (marigold) with every 10-15 rows of tomato resulted in maximum reduction of both eggs and larvae of *H. armigera* in tomato with consequent reduction in bored fruits. The rest of the trap crops tried (Okra, Dolichos, pigeonpeas, sunflower, maize) were found ineffective because they were less preferred and also flowering in these crops did not synchronize with tomatoes in India (Srinivasan *et al* 1994).

Large number of *Frankliniella occidentalis* were found in trap plants (Gloxinia, Browallia, Gerbera and Impatiens) in comparison to surrounding crops, but the presence of trap crop did not greatly reduce the level of thrips on the crops chrysanthemum in Netherlands (Hoyle and Saynor 1993).

Trap crop studies from Hawaii in cabbage fields revealed that Indian mustard and tastie

cabbage acted as effective trap crops for diamond back moth *Plutella xylostella* and cabbage-worm *Pieris rapae*. Various changes in agroecosystem management might allow the attractiveness of the trap crops to be used in a beneficial manner. Luther *et al* (1996) also suggested that understanding how lepidopteran larvae move within the vegetation would be useful for successful implementation.

Studies conducted in Ohio, USA on soybean with different cropping systems (maize monoculture, soybean monoculture, strip cropping of maize and soybean) and tillage systems (no tillage and conventional tillage) indicated no evidence of reduced herbivory in diversified agroecosystems, as predicted by the resource concentration hypothesis (Tonhasa 1994).

Studies conducted at International Centre for insect Physiology and Ecology (ICIPE) in Kenya indicated that sorghum and cowpea as the best crop combination in terms of minimizing borer population, stabilizing productivity and reducing the yield losses due to borers. The incorporation of resistant and tolerant cultivars in an intercropping system offered an added advantage by reducing the insect pest attack to farmers. The worst combination was found to be maize and sorghum (Omolo *et al.*, 1993).

Intercropping white cabbage with white clover (*Trifolium repens*) reduced the pest population in the Netherlands. Number of larvae of *Mamestra brassicae* and their feeding damage, oviposition and feeding damage by *Delia radicum*, and infestation of harvested cabbage by *Thrips tabaci* were reduced in intercrops. No differences were found in infestation of cabbage by *Contarina nasturtii* and *Phyllotreta* spp. in monoculture and intercrops. More parasitoids, carabids, staphylinids and spiders were recorded from intercrops than monocultures (Theunissen *et al* 1992).

Results from the studies conducted in Georgia, USA on the occurrence of wireworms indicated the presence of few elatrids in fallow fields. The population of elatrids was higher in crops grown after sweet potatoes, but baited traps of a maize wheat seed mixtures reduced populations significantly from sweet potato hills. Elatrids were more abundant in raised beds than between beds. Repeated ploughing reduced the incidence, and the abundance was more in weedy fields than weed-free fields (Seal *et al* 1992).

Irrigation

Soil moisture is an important factor influencing insect behavior, development and pest status directly or sometimes indirectly. The method of irrigation followed, may cause sufficient mechanical disturbance and affect past development. Flooding of rice fields for at least five days after harvest killed many larvae and pupae of rice stem borers (National Academy of Science, 1969).

Smithy and Johnson (1989) mentioned that protected irrigation would never allow the lesser corn borer to attain pest status in groundnut fields in Texas, USA, and also mentioned that not only the moisture levels but the source of irrigation are important in insect management.

Cockfield and Mahr (1992) through their studies conducted in Wisconsin, USA indicated significant reduction in the number of larvae of *Rhopobata naevana* by following 25-50 h spring flooding of caneberries.

In Denmark application of irrigation to root crops (carrot) substantially reduced the incidence of *Agrotis segetum* (Kobro 1991).

Mulching

The use of shiny plastic mulches to protect crops from aphids and virus vectors has been known for long time. The winged aphids respond positively to the short wave radiation when they are ready to initiate their dispersal flight. Thus when they are in flight they respond to short wave radiation, but are confused and reflected when they receive sky signal from the ground and ultimately fly to a non

mulched area for settling down. This plastic mulch material is available to farmers in China at affordable price.

Costello and Altieri (1993) demonstrated the reduction of aphid population in broccoli crops by using live mulching of cover crops (*Trifolium repens, T. fragiferum*, and *Lotus corniculatus*). Two fertilizer regimes were followed with each of these cover crops. The infestation by aphids was affected by the interaction of fertilizer and the cover crops. Cover crops reduced the early season light reflectance patterns at certain spectral wave bands and it was thought that this made them less attractive to the incoming aphids. Early and intensive mowing of cover crop and adequate irrigation maintained the yields of broccoli in living mulches than in clean cultivation.

In China it was suggested that ground cover with weed *Ageratum conizoides* functions as supplementary source of natural enemy for the management of citrus arthropod pests including the citrus red mite *Panonychus citri* (Liang *et al* 1994).

Black plastic did not affect the larval population of *Aulacophora similis* in heavy black soils of Guam islands but it did act as barrier and prevented the larvae from damaging the melons lying on the plastic. The yields of melon increased as a result of both plastic mulch and carbofuran application (Schreiner and Nafus 1994).

A combination of reflective mulch and oil plus insecticidal sprays was the most effective treatment in controlling aphid borne papaya ringspot poty virus in zuchini in Walkamin, Queensland, Australia. Black mulch alone was partly effective and significantly better than control. Blue and grey mulches were not effective (Pinese *et al* 1994).

Transparent polyethylene mulch reduced the populations of aphid and aleorodids and virus incidence in Mexican canaloups and increased the export quality and production. The presence of plastic mulch delayed the appearance of viral disease by 2 weeks with respect to bare soil (Orozco *et al* 1994)

Webb and Linda (1992) from their studies at Florida showed that the yields of zucchini squash increased dramatically with the use of polyethylene covers. These covers excluded *diaphania nitidalis, D. hyalinata, Bemisia tabaci*, and several colonizing aphid species. The incidence of potyvirus and silverleaf were greatly reduced by using row covers.

In field studies conducted in Alabama, USA, the average number of thrips in blooms of tomato cv. Mountain pride was greater on tomatoes grown on white plastic mulch than grown on black mulch, aluminium-colored plastic mulch or bare soil. Early season differences, however diminished with time as plants grew and shaded the larger portion of the mulch (Brown and Brown 1992)

Studies organized in Sweden on effect of mulches and intercropping on the incidence of carrot fly resulted in no effect of mulches on carrot fly population. The only treatment which clearly and consistently reduced the fly population was intercropping with *Medicago littoralis*, however this treatment did not increase the yields of carrots (Rambert 1993).

Rice straw mulch application soon after soybean sowings in Indonesia reduced the incidence of plant mortality caused by *Ophiomya phaseoli* relative to untreated plots. Mulches also resulted in controlling *Melanagromyza sojae* another important insect pest of soybean (Hirano *et al* 1993).

Application of crushed mustard seed as mulch in cabbage fields in Sweden reduced the damage by larvae of *Delia radicum*. Individuals of *Aleochara bilineata, A. bipustulata, D. platura*, and *D. florilega* were strongly attracted by mustard meal. The main advantage of this mulch was

that they attracted *A. bipustulata* during the oviposition period of the pest (Ahlstrom and Jonasson 1992).

In Korea both transparent and black plastic mulches reduced the likelihood of larval damage in soybean fields (Kim 1992).

Intercrops/ Trapcrops

Growing more that one crop in the same land is a common practice in marginal and subsistence farming in Asia and Africa. Mixed cropping in the traditional agriculture serves as an assurance against risk factor, better utilization of resources and quite often serves to overcome insect menace. Monoculture in general favors insect pests, on the other hand crop diversity provides opportunity for increased colonization, reproduction of parasitoids and predators, thus reducing pest colonization and damage. (Bhatnagar and Davies 1981).

Puspitorini (1992) from Indonesia highlighted the role of intercropping cabbage with garlic in the management of *Thrips tabaci, Plutella xylostella* and *Crocidolomia binotalis*. Intercropping with garlic reduced the number of *P. xylostella* and *T. tabaci*, whereas the population of *C. binotalis* was unaffected.

Natarajan *et al* (1991) from Tamil Nadu, India showed that populations of *Ophiomya phaseoli* on *Vigna mungo* and *Bemisia tabaci* on cowpea were increased by intercropping with maize. The incidence of yellow mosaic was lower in intercrops of *V. radiata* with maize and sorghum than monocultures. Conversely podborer damage to *V. radiata* was lower in monoculture than intercrops.

Singh *et al* (1991) from Delhi, India indicated that intercropping groundnut with pigeonpea or greengram needs something else here. *Vigna radiata* increased the incidence of *Myllocerus identifer* and *Spilosoma obliqua*. Intercropping with sorghum reduced the incidence of *E. kerri, C. indicus, Spodoptora litura* and *S. obliqua* and increased the incidence of *M. dentifer*. Intercropping with sesame had no effect on insect pests. Although intercropping reduced the incidence of insect pests, it did not result in higher yields. However this indicated pigeonpea and groundnut combination as the most remunerative. In another study the above authors showed that intercropping pigeonpea, greengram, soybean and sesame with groundnut accelerated the incidence of homoptern pests, where as intercrop with sorghum helped in the reduction of *B. tabaci* (Singh *et al* 1991b).

Yadav *et al* (1992) evaluated the effects of six intercrops on the incidence of Bihar hairy caterpillar and its parasites in Bihar, India. The highest pest population was observed in pure crops, while intercropping black gram, maize, castor, and/or sesamum with pigeonpea resulted in lowest pest population. The rate of natural parasitism by *Trichogramma chilonis* and a species of genus *Meteorus* was relatively high in pure crops of castor, followed by black gram. The activity of other parasites was unaffected by intercropping.

Recent studies from All India Co-ordinated Research project on Improvement of Chickpea (ICAR, AICRPIC Annual Report 1996-97) indicated that intercropping wheat, coriander, safflower and sunflower with chickpea considerably decreased the podborer damage to 5-6% compared to 16% in sole crop.

Trap crops

Ampong Nyarko and co-workers (1993) in Kenya studied the use of intercrop as trap crops in the management of *Chilo partellus* in sorghum-cowpea, maize -sorghum-cowpea and maize-cowpea intercropping systems. The eggs that were laid on non host plant after hatching were unable to reach the main host. Thus *C. partellus* oviposition on non host plants is the mechanism for reduced infestation on sorghum intercropped system.

Experiments conducted by Giraldo during 1993 in Columbia on trap crops such as tomato, aubergine and sunflower in tobacco fields showed strong preference of *Faustinus apicalis* towards aubergine. Tobacco plots with aubergine suffered only mild attack and resulted in 43% higher yields.

Field studies conducted by Wu *et al* (1991) in Shaanxi, China showed that interplanting maize in cotton increased the population of Araneae, coccinellidae and Chrysopidae by 63-116% compared to control plots. Maize also acted as trap crop for *Helicoverpa*, reducing the 2nd generation there by the main crop escaped the damage substantially.

Studies conducted by Gangwar and others (1994) in the mid and high altitudes of Meghalaya, India indicated low incidence of insect pests in intercrops involving rice, maize, soybean and groundnut as compared with the monocrops. The reason for the low insect populations was primarily thought to be due to the change in the microclimate.

Inter/mixed cropping of chickpea with barley wheat, mustard, linseed and coriander reduced pod borer damage by *Helicoverpa* and increased yields of chickpeas in India (Sachan and Lal, 1998, Chauthan, 1992, Thakur *et al* 1992, and Sachan 1993).

Groundnut : A Case Study

Insect pests are recognized as major biotic constraints in groundnut cultivation. Foliar insects such as leaf miner [*Aproaereme modicella* (Deventer)], tobacco caterpillar [*Spodoptera litura* (F)] are important in southern India. Among sucking pests, thrips [*Thrips palmi* (Karny.)] and aphids [*Aphis craccivora* (Koch.)] are only important as vectors of viral diseases. White grubs (*Lachnosterna* spp.) are important soil insects in northern India. In the recent years, groundnut pest management strategies are mostly concentrated on developing integrated approach combining various options such as host-plant resistance, cultural, biological, mechanical and chemical control. Most of information on pest management that has been developed is in fragments and the strategies developed were followed independently. Farmers are known to apply excessive amount of insecticides on this crop particularly in post rainy season irrigated situations. Though the action thresholds for key insect pests are defined, they were not widely demonstrated and used by farmers. The role of natural enemies is underestimated and no attempt has been made to take advantage of their presence. The importance of mixed and intercrops, crop rotation, sowing dates, though every well understood, their knowledge as pest management tools is limited. Thus the results from individual pest management components need to be knitted together to achieve better results. Though the present scene of pest management is mostly dependent on chemicals, future strategies are going to change as research results from alternative methods of control became available. The successful examples of cultural practices are furnished in Table 1.

1. Effect of overhead irrigation on mites :

During 1989-90 post rainy season there was an outbreak of red spider mites on of the ICRISAT's groundnut fields. The mite populations was so dense the harvesters refused to enter the field, because of the skin irritation caused by the mites. The crop was at maturity and rapid action was needed. We did not want another insecticidal application to avoid further flare up and health hazard to harvesters. After thorough analysis of various situations in the farm the clue for this type of population was known. This was mainly due to excessive use of insecticides and fungicides. The fields where overhead irrigation was employed the mite population was not high. Keeping this in view we immediately provided overhead irrigation to the field. The results in the table indicated that there was an immediate response to the treatment and the mite population declined by 80% (Table 2). This is an example of how a crop management practice can influence the popula-

Table 1. Effect of cultural operations on groundnut pests.

OPERATIONS	PEST	EFFECT	REFERENCE
Intercropping			
Cowpea, Blackgram	Leafminer	Reduced larval population and damage	Logiswaran and Mohansundaram 1985.
Pearlmillet	Leafminer	Reduced populations and damage	Murali Baskaran and Thangavelu 1990.
Pearlmillet, cowpea, sorghum	Jassids, Thrips and Aphids	Reduced populations and low incidence of BND	Kennedy *et al.*, 1990. DVRR *et al.*, 1991.
Pigeonpea	Jassids and Thrips	Populations were higher than in sole crop.	Singh *et al.*, 1991.
	Grasshopper	No effect.	- do -
	Whitefly	Less in intercrop	Singh *et al.*, 1991b
Soybean	Leafminer	Population reduced with increased parasite activity	Wightman & Rama Rao 1994
Sunflower/Castor	Spodoptera/ Helicoverpa	Reduced damage	Ranga Rao *et al.*, 1995.
Spacing			
Close (30 x 10 cm)	Thrips	Low thrips injury and bud necrosis	DVRR *et al.*, 1991
Planting date			
Early planting	Thrips	Low thrips injury shed by necrosis	DVRR *et al.*, 1991.
Irrigation			
Overhead irrigation	Aphids and mites	Reduced populations	Ranga Rao *et al.*, 1990
Time of Irrigation	Spodoptera	Populations reduced due to activity of birds and other predators during day time	Whightman and Ranga Rao 1993.
Flooding	White grubs	Population reduced	Veeresh 1977
Moisture	Aphids	Optimum moisture increase the population	Ranga Rao *et al.*, 1991.
Light traps	Red hairy caterpillar	Population and damage reduced in number of kharif crops	Qayum & Sanghi 1994
Adult collection	White grubs	Reduced population and damage	Yadava 1995
Mulch	Aphids, Jassids, Leafminer	Population reduced No effect	Ranga Rao (in press)
Field burning	Spiders	Reduced population	Ranga Rao 1996

tion densities of potential pest, in this case physical factor of water falling on the mites and dislodging them to the ground and causing mortality.

2. Line source irrigation and aphids

The groundnut aphid is generally considered as pest of groundnut in rainy season crop in southern India. But during 1989-90 post rainy season unusually this species attained pest status at ICRISAT center. This gave us an opportunity to look into the aphid distribution across the water-stress gradient created by a line source overhead sprinkler irrigation system. Two different water stress situations were created i.e., one was continuous water stress which was imposed from 40

Table 2. Spider mite density on groundnut plants as influenced by different irrigation systems and pesticide regimes, ICRISAT Center, 1990.

Nature of irrigation system	Insecticides	Mites per 50 leaflets1	
		Before overhead irrigation 18 Apr 1990	After overhead irrigation 23 Apr 1990
Furrow	Yes	6323	1282
Overhead	Yes	110	18
Furrow	No	64	13
SE		±43	±69

1. Samples of 50 leaflets were removed at random from plants growing in five parts of each field. Data are the means of the five samples.

days after sowing (DAS) and the other was end off season stress induced at 80 DAS. The observations on aphid populations were taken on week after the imposition of end off season stress on 40 terminals and three replications. The results in figure 1 indicate that the aphid populations was much higher in plants that had sufficient moisture. The difference in population from wet to totally dry gradient was significant. There was clear cut negative relationship in population development as the distance from the water source increased. Two days after the aphid counts there was 70mm rain on the farm. The observations immediately after the rain showed that there was 90% decline in population. The effect of rain water on aphid population suggest the physical effect of water landing on the plants reducing the population significantly (Ranga Rao *et al* 1991).

3. Overhead irrigation and thrips :

Thrips can be of economic importance in groundnut both as direct pests and as vectors of bud necrosis virus. Due to their rasping and sucking type of feeding on young leaves, leaflets develop irregular brown patches on the leaves. Thrip damage is more apparent in young crops particularly during post rainy season in India. So far chemical control is the only means of control for thrips. Some observations made on the effects of different overhead irrigation systems on the populations of thrips indicated the following. During post rainy season, 1990 observations on thrips populations on three different irrigation systems indicated significant reduction of population in overhead irrigation than normal furrow system. Groundnut crop under overhead irrigation (Perfo, Sprinkler) had 50-75% less thrip population resulting in about 10% thrip injury to foliage compared to 20% in normal irrigation system (Table 3). Between perfo and sprinkler the latter had lower thrip population which could be due to the larger water particles falling on the terminals than in perfo irrigation. Thus the populations of suck-

Table 3: Effect of irrigation systems on groundnut thrip populations observed at ICRISAT Center during postrainy 1990.

Irrigation method	Number of thrips[1]/ termina	Thrips damaged [2] leaflets %
Furrows	3.9	19.8
perfo	2.4	8.6
Sprinkler	0.9	11.0
SE	±0.08	±0.7

1. Mean of 100 termites and five replicates
2. Mean of 50 plants and five replications

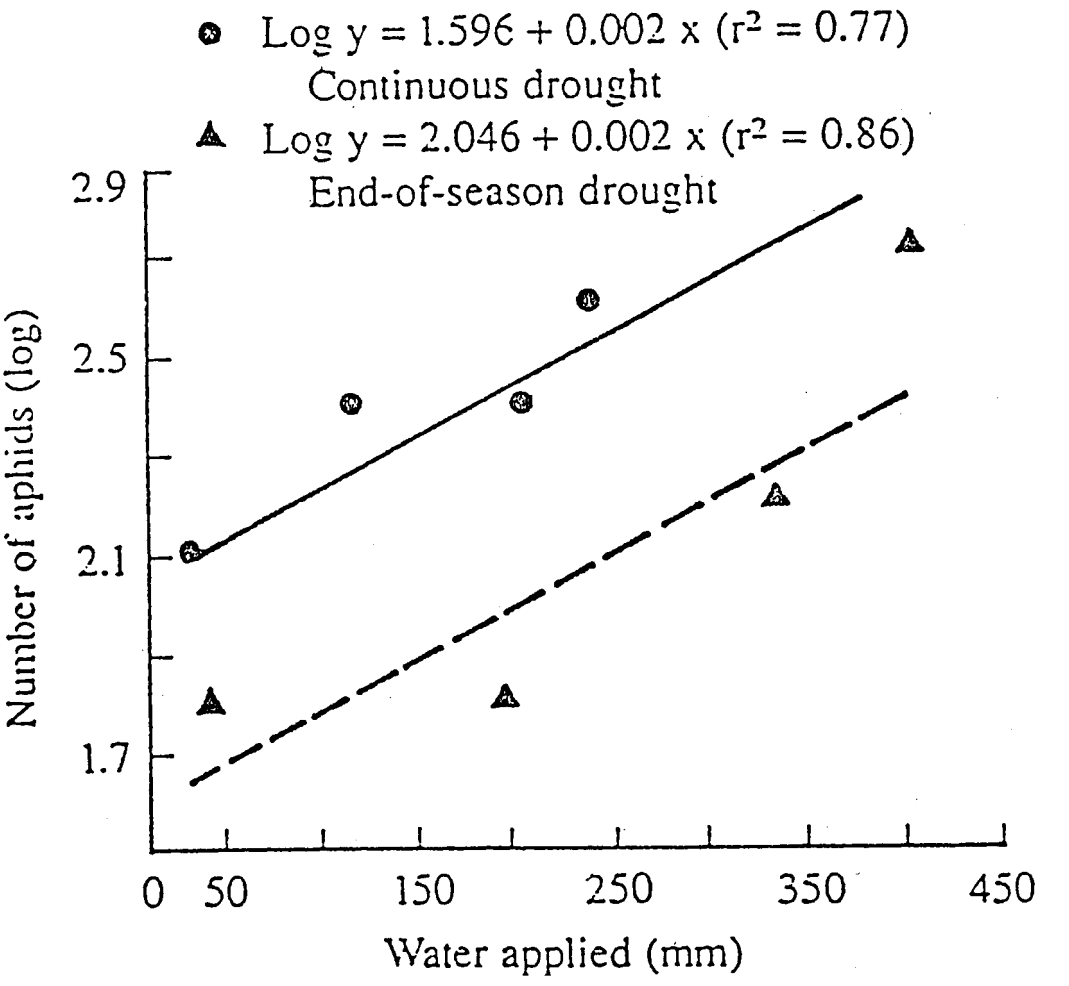

Fig. 1: Distribution of aphid populations across a drought-stress gradient created by line-sources overhead irrigation

ing insects such as aphids, thrips and mites can be managed with overhead irrigation system alone.

4. Polyethylene mulch and insect pests :

Mulches are known to interfere with different insect activities and provide good shelter for some species otherwise the populations decline. In recent years use of synthetic mulches such as polyethylene are used widely in agriculture for different purposes. At ICRISAT observations made on the effect of polyethylene mulch in groundnut crop revealed some encouraging results. The crop was sown on the white polyethylene mulch with 30cm row to row spacing and 15cm plant spacing. Observations on plant growth, thrips populations, thrips injured foliage, jassid populations, jassid injured foliage and leafminer populations were taken. These observations showed that polyethylene mulch had profound effect on the plant growth throughout the crop phase which could be due to high soil temperature during the initial phase of the crop. There was four fold difference in thrips population which reflected in six fold difference in thrip injury be-

tween mulch and no mulch situations (Fig 2). Similarly there was 50% reduction in jassid population and injury in mulched area compared to non mulched crop. These differences were not envisaged due to the full canopy cover by early March, however there were significant differences noticed which could be due to the micro climatic effects of the mulch in affecting the behavior of the jassids. The observations on the groundnut leafminer indicated no effects of mulch throughout the cropping period (Table 4). This could be explained by the nocturnal behavior of the leafminer adults where the effects of mulch were insignificant. These type of mulches are very popular in different parts of the world on several crops. For example, in China it is extensively used in groundnut and other vegetable crops particularly meant for preserving the soil temperature and curtailing the weed growth. However their effectiveness and economic feasibility in different crops in other developing countries is yet to be understood.

5. Flood irrigation and white grubs :

Among various cultural operations flooding the fields, puddling and rice cultivation gave excellent control of white grubs in India. Only flooding and allowing the soil to dry up had not yielded much success. When the land is flooded the active grubs come out of the soil and when water recedes the grubs go back in to the soil hence prolonged flooding for 7-10 days is necessary. This type of operation may not be possible in all situations but where ever the water is available this strategy can be followed for at least two seasons to avoid white grub damage and to lower the populations (Veeresh 1977).

6. Manual picking of white grub adults from feeding sites :

The adults of white grubs emerge immediately after the first monsoon rains and feed on several perennial trees mostly Neem, Acacia and Ber. The adult emerge soon after dark around 19.00 hours and aggregate on the feeding sites. Catching and killing the adults from feeding sites was found effective in minimizing the populations and the damage. If the collection is attended consciously by the whole village this would be the cheapest and most effective approach in minimizing this pest. This approach was tried in Karnataka and Rajasthan and more than 1,00,000 beetles were collected on the first day of emergence by over 100 farmers. Providing smoke with paddy straw underneath the host trees is effective in dislodging the adults from the feeding sites. This catch and kill approach is more effective than chemical application on feeding site to kill the adults. (Yadava 1995).

7. Trap crops and Spodoptera and Helicoverpa management:

Like other living organisms insects also show considerable preference for their oviposition and feeding. After gaining some relevant information in this field, plant protectionists started putting this knowledge into practice. The two most important defoliators of groundnut prefer castor or sunflower for oviposition and larval feeding. Another important change in *Spodoptera* larval behavior on these preferred hosts is significant. The newly hatched larvae disperse immediately into the crop if they are on groundnut, while, if they are on sunflower or castor they stay at the oviposition site for a week to ten days. This is an excellent opportunity to collect and destroy the pest without involvement of chemicals. Since these crops are preferred by the pests, as long as the trap crop foliage is available in the main field the main crop will not be preferred by the pest. Castor and sunflower had greater amounts of foliage to support large number of caterpillars which gives some time for the pest to devour the trap crop and then move to the main crop. It was clearly noticed that by the time the trap crop is completely defoliated the main crop escapes the vulnerable stage. Thus this simple technology can be exploited very well in groundnut IPM for the management of defoliators.

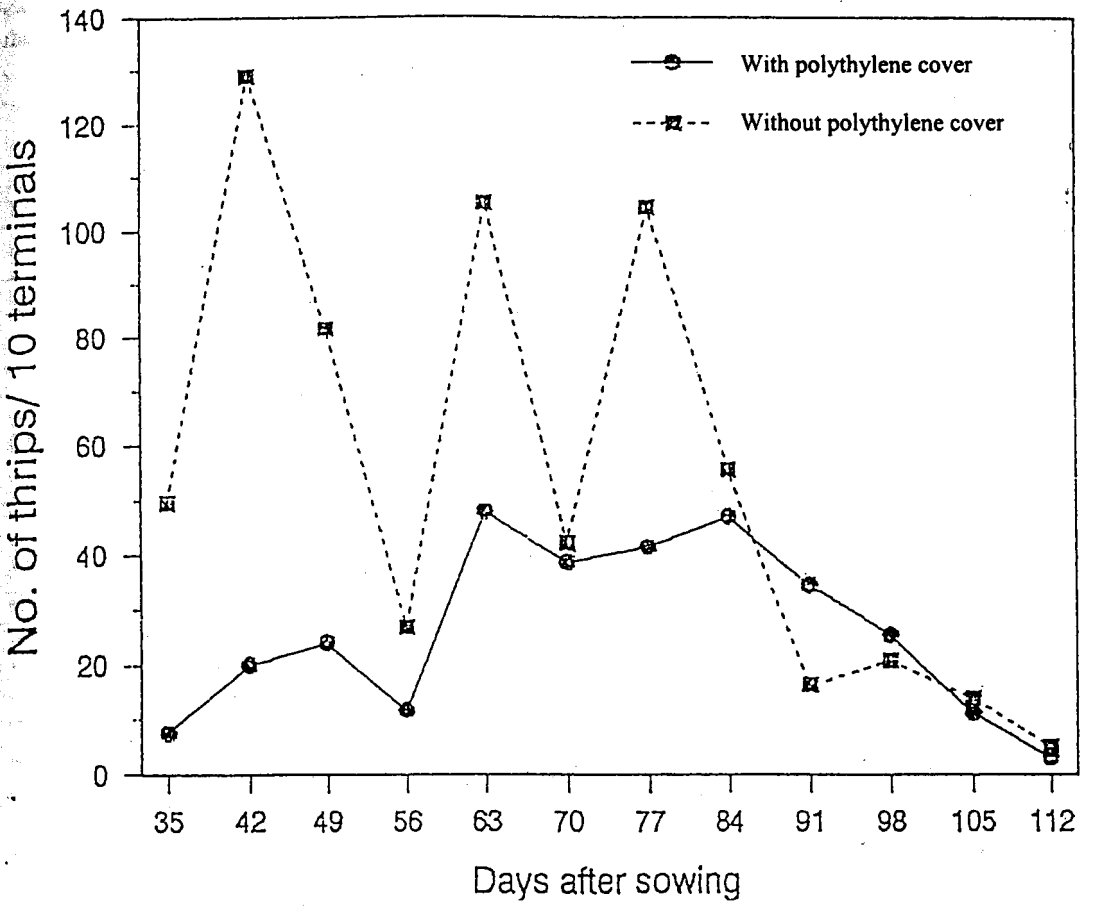

Fig. 2 : Effect of polythylene mulch on groundnut thrips population

Table 4. Effect of polyethylene mulch on some groundnut insects observed at ICRISAT Center during postrainy 1991-92.

Treatment	Insect pests				
	Thrips/10 shoots	Thrips damaged leaflets (%)	Jassids/10 plants	Jassid infestation (%)	Leafminer larvae/10 plants
With polyethylene mulch	3.6	4.6	47.0	10.9	68.2
Without mulch	16.6	24.3	92.8	20.7	64.8
SE	±1.95	±0.92	±4.04	±1.08	4.44

1. Mean of 5 replications and 10 plants in each sample.

8. Groundnut/cereal intercrop for Leafminer control :

Though several methods have been recommended for control of leafminer in groundnut, rotation of groundnut with nonleguminous crops, avoiding groundnut with soybean to prevent outbreaks has been suggested to reduce the leafminer populations (Feakin, 1973). Lower leafminer populations have been found when groundnut was intercropped with sorghum or millet than in monoculture groundnut with 30x10 cm spacing (Logiswaran and Mohansundaram, 1985, Murali Bhaskaran and Tahanvelu, 1990). Though intercropping interferes considerably with yields, since it contributes significantly for the pest management it is worth including this option as one of the components of IPM.

9. Light traps and other cultural measures to control Red hairy caterpillars:

Red Hairy caterpillar is a dangerous pest of several crops in the southern part of India during rainy season. For the past one decade farmers used only pesticides to keep the pest under control. While looking at various alternate options initially bonfires were tried with considerable success. This was done with the available indigenous material which could yield isolated success. Later this technology has been improved by placing one light trap for every 10 ha of cultivated land. More than 15 voluntary organizations participated in this program by coordinating at different villages. The basic principle behind this program was to develop a nonchemical pest control approach, using indigenous material, encouraging group action, with simple and low cost technology. The impact of this program indicated substantial control of this pest in wider areas. In the untreated villages 56% area was totally damaged compared to 3% crop loss in treated villages. This program brought out some excellent results, however there were some limitations regarding the operation of traps in interior places, where uninterrupted power sources are not available. Though there are some constraints with sincere involvement of the whole community this project could achieve good success.

10. Time of Irrigation and Bird Predation:

Some insectivorous birds contribute considerably to insect pest control. Though this is a well known fact, the quantification of the contribution from insect predation by birds is a difficult exercise. The pests that are nocturnal in habit can escape the bird predation successfully. *Spodoptera* larvae hide in the litter underneath the plants during the daytime and feed on the crop in the night. These larvae can be exposed to the bird predation by providing irrigation during the day time. When the soil is saturated to the capacity the larvae start climbing the plants, and the birds can have a feast. Flocks of egrets in irrigated fields feeding on *Spodoptera* caterpillars is a common sight. It is a well known fact that if the predatory birds are active in any groundnut field one need not worry about the defoliators at all. Birds reduce 15% *Spodoptera* and 90% *Helicoverpa* larval populations in 7 days and 24 hr respectively under experimental conditions. Providing perches in groundnut fields helped in attracting drongoes by facilitating effective natural insect control process (Ranga Rao *et al* 1994)

11. Pulling a thorny branch on groundnut crop to disturb leafminer :

Groundnut leafminer due to its feeding and living habits poses several problems in control strategies. Due to its mining habit in the early stages and webbing at later stages the application of contact insecticidal dust formulations are very popular in the rainfed zones of India. Farmers prefer dust formulations because of easy application and the non-availability of sufficient water for taking up sprays or difficulties in transporting large quantities of water. To improve the effectiveness of dusts, farmers developed a technique to disturb the webs before the application of dusts. To achieve this a light thorny branch is pulled over the crop. This operation disturbs the

webs and the larvae are exposed to environment followed by the application of chemical. Some times the physical stress of disturbance, exposure to natural enemies and the harsh environment can contribute to the population reduction.

Conclusions

Many cultural practices are known to influence insect populations. Most of these cultural practices are simple, less expensive and easily followed by the farmers. To achieve maximum benefits community involvement plays a critical role. There is a great need for sharp focus on systems approach to develop and integrate various aspects of IPM to take advantage of existing farmers cultural practices. This strategy will enable the farmers to overcome or minimize, the pest problem over long run in an environmentally safe, economically feasible and effective manner. Extension system plays important role in implementing such strategic components of pest management. Developing extensive data base for cultural control need collaborative efforts and the involvement of several disciplines. Thus the following suggestions are made :

1. Basic studies are urgently needed to determine the effects of various cultural operations on microhabitat there by production system.

2. An interdisciplinary research approach need to be developed and cultural practices designed to enhance the influence of other control agent.

3. It is impossible to study all combinations of crops, pests, natural enemies, environment, and cultural operations and their interrelationships. Therefore development of system wide pest models should be given high priority.

4. The successful case studies in different crops/ locations need to be studied in newer areas with necessary modifications.

References

Aganon, T.M. 1989. Cultural control against soybean insect pests (Philippines) conference paper presented in pest control councel of Philippines, Baguio city, during 9-12 May 1989.

Ahistrom -Olsson, M., and Jonasson, T. 1992. Mustard meal mulch-a possible cultural control method for attracting natural enemies of brassica root files into brassica crops. Bulletin-OILB-SROP 15(4) : 171-175.

Ali, M.A. 1993. Effects of cultural practices on reducing field infestation of potato tuber moth (Pthorimea operculella) and greening of tubers in Sudan. Journal of Agricultural Sciences 121(2) : 187 - 192.

Alighali, A.M. 1993. Intercropping as component in insect pest management for grain cowpea, Vigna unguiculata walp production in Nigeria. Insect Science and its Application 14(1) : 49-54.

All India Co-ordinated Research Project on Improvement of Chickpea (ICAR) Annual Report 1996-97.

Ampong Nyarko, K., Reddy. K.V.S., and Saxena, K.N. 1993. Chilo partellus (Swinhoe) oviposition on non-hosts: a mechanism for reduced pest incidence in intercropping. Acta - Oecologica 15(4):469-475

Begum, N., Hussain. M., and Chowdury, S.I. 1992. Effect of sowing date and plant density on pod borer incidence and grain yields chickpea in Bangladesh. International Chickpea News letter 27:19-21.

Bhadauria, N.S., Bahadur, J., Dhamdhere, S.V. and Jakhomola, S.S. 1992. Effect of different sowing dates of mustard crop on infestation by the mustard aphid, Lipaphis erysimi (Kalt.) Journal of Insect Science 5(1) : 37-39.

Bhatnagar, V.S. and Davies, J.C. 1981. Pest management in intercrop subsistence farming 249-257 pp. *In* Proceedings of the International Workshop on Intercropping, 10-13 Jan 1979, Hyderabad, India.

Brown, S.L., and Brown, J.E. 1992. Effect of plastic mulch color and insecticides on thrips populations and damage to tomato. Hort Technology 2(2) : 208-210.

Chamberlin, J.R., Todd, J.W., Culbreath, A.K., Johnson, W.C., and Demski, J.W. 1993. Post-harvest management of tobacco thrips (Thsanoptera: thripidae) overwintering in peanut fields. Journal of Entomological Science 28 (4) : 433-446.

Chand, P., and Sharma, N.N. 1977. Influence of crop association on insect pest incidence. Proc. Indian Nat. Sci. Acad. 43 : 108-114.

Chauhan, R. 1992. Present status of *Helicoverpa armigera* in pulses and strategies for its management in Haryana. 49-54 pp. In: *Helicoverpa* Management : Current status and future strategies (Ed Sachan, J.N.). Proceedings of First National Workshop held at Directorate of Pulses Research, Kanpur, India 30-31 August 1990.

Chaudhary, O.P., Rataul, H.S., and Sandhu, G.S. 1993. Management of flat - headed borer, Sphenoptera dadkhani Obenberger on peach in India. India Journal of Pest Management 39(1) : 75-79.

Chaudhary, O.P., and Kashyap, R.K. 1992. Effect of some management practices on the incidence of insect pests and yields of egg-plant (Solanum melongena) in India. Tropical Pest Management 38 (4) : 416-419.

Choldumrongkul, S., and Atirattanpunya, W. 1993. Shoot production and the damage of pests and diseases of Pai ruak (Thyrsostachys siamensis Gamble) after different thinning intensities. Kasetsart Journal Natural science 27(1) : 20-24.

Cockfield, S.D., and Mahr, D.L. 1992. Flooding caneberry beds to control blackheaded fireworm (Lepidoptera : Tortricidae) Journal of economic Entomology 85(6) : 2383-2388.

Costello, M.J., and Alteri, M.A. 1993. Living mulches suppress aphids in broccoli. California Agriculture 48(4) : 24-28.

Dissemond, A., and Hindorf, H. 1990. Influence of sorghum/maize/cowpea intercropping on pest, disease, and weed situation at Mabita/Kenya. Proceedings of Integrated Pest Management in Tropical and subtropical cropping Systems no. 3:843-851.

Dubois, D., Hani, A., Ammon, H.U., and Keller, S. 1993. Influence of weed control on sugar yield and the spread of yellow virus insugar beet crops 6(3) : 133-138.

Ekukole, G. 1992. Primary results on the effect of pruning cotton plants on aphids gossypii Glover populations in Maroua, North Cameroon. Cotton at Fibers-Tropicales. 47(2) : 13-138.

Feakin, S.D. 1973. Pest control in groundnut. PANS Manual No 2 (3rd ed.) UK. Centre for Overseas pest Research, London. 197 pp.

Funderburk, J.E., Teare, I.D., and Rhoads, F.M. 1991. Population dynamics of soybean insect pests vs. soil nutrient levels. Crop Science 31 (6) : 1629 - 1633.

Gahukar, R.T. 1991. Pest status control blister beetles in West Africa. Tropical Pest Management 37 (4) : 415 - 420.

Gangawar, S.K., Singh, S.P., and Patel C.S. 1994. Influence of intercropping on infestation by insect pests of crops in medium high altitudes of Meghalaya. Indian Journal of Agricultural Sciences 64(2) : 134-140.

Ghini, R., Bettiol, W., Spadotto, C.A., Moraes, G.J. de., Paraiba, L.C. Mineiro. J.L. de., C., and De. Moraes, G.J. 1993. Soil solarization for the control of tomato and egg-plant Verticillium Summa. Phytopathologica 19 (3-4-) : 183-189.

Giraldo, A.S. 1993. Trap crops for the control of tobacco, stem borer, Faustinus apicalis (Faust) Coleoptera : Curculionidae). Revista. Colombia-de-Entomologia 19 (4) : 139-142.

Hatmosoewarno, S. 1970. Fertilizers in relation to pests and diseases. Sugar. Path. Newsl. 5:23-24.

Hirano, K., Hassan, K., and Alimoeso, S. 1993. Effect of rice straw mulch on controlling beanflies (Diptera: Effect of rice straw mulch on controlling beanflies (Diptera: Agromyzidae) in soybean fields in Indonesia. Applied Entomology and Zoology. 28(2) : 260-262.

Hoyle, E.J., and Şaynor, M. 1993. Observation on the effectiveness of trap plants for the control of western flower thrips (Frankliniella occidentalis). Bulletin - OILB-SROP. 16.8 :102-104.

Hudon, M., and Khanizadeh, S. 1993. mortality of overwintering larvae of European corn borer, Osrinia nubilalis hubner, from conventional tillage practices of maize field debris. Journal of Agricultural Entomology 10(2) :121-124.

Isler, N., and Ozgar, A.F. 1992. The effect of planting time and row spacing on population development of whitefly (Bemisia tabasi) and plant phenology and yield. Turkiye Entomologi Dergisi 16(2) : 87-98.

Kennedy, F.J.H., Rajmanickam, K. and Raveendran, T.S. 1990. Effect of intercropping on insect pests of groundnut and their natural enemies. J. Biol. Control 4(1) : 63-64.

Kfir, R. 1990. Prospects of cultural control of the stalk borers, Chilo partellus (Swinhoe) and Busseola fusca (Fuller), in summer grain crops in South Africa. Journal of Entomological society of South Africa 53(1) : 41-47.

Kim, T.H. 1992. Delia platura as a soybean insect pest. Korean Journal of Applied Entomology 31(2):174-181.

Kobro, S.1991. Irrigation against cutworm. Gartneryrket. 81 (21) : 22-23.

Kumar, Y., Singh, Z., and Khokhar, K.S. 1992. Influence of intercropping with blackgram on application for the control of borer pests of pigeonpea. Journal Insect science 5(2) : 214-216.

Letourneau, D.K. 1993. Bean fly, management practices and biological control in Malawian subsistence agriculture. Agriculture, -Ecosystem- and - environment 50(2) : 103-111.

Liang, W.G., Huang, M.D., Prokopy, R.J. and Coli, W.M. 1994. Influence of citrus orchard ground cover plants on arthropod communities in China. Agriculture ecosystem and environment 50 (1) : 29-37.

Liquido, N.J. 1993. Reduction of oriental fruit fly (Diptera : Tephritidae) populations in papaya orchards by field sanitation. Journal of Agricultural Entomology 10(3) : 163-170.

Logiswaran, G., and Mohansundaram, M. 1985. Effect of inter-cropping, spacing and wulching in the control of groundnut leafminer. Aproaerema modicella Deventer (Gelichiidae : Lepidoptera). Madras Agric. J. 72:695-700.

Luther, G.C., Venezuela, H.R. and Defrank, J. 1996. Impact of cruciferous trap crops on lepidopteran pests of cabbage in Hawaii. Environ-entomol. 25(1) : 39-47.

Mack, T.P., and Backman, C.B. 1990. Effect of two planting dates and three tillage systems on the abundance of lesser cronstalk borer (Lepidoptera : Pyralidae) other selected insects, and yield in peanut fields. Journal of Economic Entomol. 83(3) : 1034-1041.

Mahadevan, N.R., and Chelliah, S. 1975. Influence of intercropping legumes with sorghum on the infestation of the stem borer, Chilo partellus (Swinhoe) in Tamil Nadu. Trop. Pest Manage. 32:162-163.

Malaka, S.L.O. 1972. Some measures applied in the control of termites in parts of Nigeria. Nigerian Entomologists Magazine 2: 137-141.

McPherson, R.M., Bondari, K., Stephenson, M.G., Severson, R.F., and Jackson. D.M. 1993. Influence of planing date on the abundance of tobacco budworm (Lepidoptera: Noctuidae) and tobacco aphid (homoptera : Aphididae) on Georgia flue cured tobacco. Journal of Entomological Science 28(2) : 145-167.

Murali Baskaran, R. and Thangavelu, S. 1990. Influence of intercrops on the incidence of leaf miner (Aproaerema modicella Deventer) in groundnut J. Oilseed Res. 7:143-146.

Natarajan, N., Rao, P.V.S., and Gopal, S. 1991. Effect of intercropping of pulces in cereals on the incidence of major pests. Madras agricultural Journal 78 (1-4) :59-67.

National Academy of Sciences. 1969. Insect pest management and control. NAS Publication No. 1695.

Orozco, S.M., Lopez, A.D., Perez, Z.O., and Delgadillo, S.f.1994. Effect of transparent mulch, floating row cover and oil sprays on insect populations, virus diseases and yield of cantaloup. Biological Agriculture and horticulture. 10(4):229-234.

Omolo, E.O., Nyambo, B., Simbi, COJ., and Ollimo, P.1993. The role of host plant resistance and intercropping in integrated pest management (IPM) with specific reference to Oyugis project. International Journal of Pest Management 39 (3):265-272.

Peterson, S.S., Wedberg, J.L., and Hogg, D.B. 1992. Effect of cutting and burning birdfoot trefoil grown for seed on the trefoil seed chalcid (Hymenoptera: Eurytomidae). Journal of the ansas Entomological Society 65 (3):292-298.

Pinese, B., Lisle, .T., Ramsey, M.D., Halfpapp, K.H., Faveri, S.de., and Faveri, S.1994. Control of aphid borne papaya ringspot poty virus in Zucchini marrow with reflective mulcu and mineral oil-insecticide spray 40(1):81-87.

Puspitorini, R.D., Mudjiono, G., and Istianto, M.1992. Effect of intercropping cabbage with garlic in the population of Thrips tabaci Lindeman, Plutella Xylostella Dan, Crocidolomia binotalis Zeller. Agrivita 15(2):34-38.

Qayum, M.A. and Sanghi, N.K.(Ed.) 1994. Red Hairy Caterpillar Management through Group Action and Non-Pesticidal methods. Programme Coordinated by ASW &

Oxfam (India) Trust, ??

Rambert,B.1993. Mulch with grass and bark and intercropping with Medicago litoralis against carrot fly (Psila rosae F.). Biological Agriculture and Horticulture 9(2):125-135.

Ranga Rao, G.V., Wightman, J.A., and Rameswar Rao, V. 1994. Birds as Control Agents in Groundnut Crop. First National Symposium on Birds in Agricultural Ecosystem. December22-24, 1994. Organized by Society for Applied Ornithology (India), Hyderabad, Andhra Pradesh.

Ranga Rao, G.V., Wightman, J.A., Arjuna Rao, P., Mahesh Baba, V., Sitarama Rao, G., and Rameswar Rao.V. 1995. Integrated management of groundnut insect pests. Pages XXX in the proceedings of the symposium, "Integrated Pest Management and Environment" 2-4 February, 1995, organized by Plant Protection Association of India in collaboration with FAO, Directorate of Plant Protection, Quarantine & Storage, Govt. of India and Directorate of Agriculture, Tamil Nadu. Breeze Hotel, 850, poonmalle High Road, Madras 600 010.

Ranga Rao,G.V., Ranga Rao, D.V., Prabhakar Reddy, M. and Wightman, J.A. 1990. Overhead irrigation and the integrated management of spider mites in a groundnut crop. International Arachis Newsletter 8:23-24.

Ranga Rao.G.V., Wightman, J.A., Wadia, K.D.R., Ranga Rao, D.V., and Nageswar Rao, R.C.1991. Influence of water stress on aphids. International Arachis Newsletter 9:14.

Ranga Rao, G.V. 1996. Groundnut entomological work during spring 1995/96, Vietnam, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru Andhra pradesh, 502 324, India.pp.109.

Reddy, D.V.R., Wightman, J.A., Beshear, R.J., Highland, B., Black, M., Sreenivasulu, P., Dwivedi, S.L., Demski, J.W., McDonald, D., Smith Jr., J.W., and Smith D.H. 1991. Bud Necrosis: A disease of groundnut caused by tomato spotted wilt virus. Information Bulletin No.31, International Crops Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, 502 324, India.

Richardson, A.J., Everitt, J.H., Summy, K.R., and Crawford, M.M. 1992. Monitoring the Rio Grand Valley Cotton stalk destruction program with satellite imagery. geocarto. International 7(2): 15-20.

Roth, G.W.; Calvin, D.D., and Lueloff, S.M. 1995. Tillage, Nitrogen timing, and planting date effects on western corn rootworm injuri in corn. American Society of Agronomy. 87(2): 189-193.

Roberts, P.M., and All, J.N. 1993. Hazard for fall armyworm (Lepidoptera: nocuiidae) infestation of maize in double-cropping system using sustainable agricultural practices. Florida Entomologist 76(2) :276-283.

Sachan, J.N. 1983. Insect and Pest management. 20-21 and 66-69 pp. In: Shifting Cultivation in North East India, ICAR Publication.

Sachan, J.N. and Lal, S.S. 1988. Changing Pest complex in relation to cropping systems - pulses: paper presented during the National Seminar on Changing Pest Situation in the Current Agricultural Scenario of India, Feb 14-18, 1988 at IARI,New Delhi.

Schreiner, I.H., and Nafus, D.M. 1994. Soil insecticides, plastic mulch and adult control as methods of reducing populations of larval Aulacophora similis (Coleoptera: Chrysomelidae) in cantaloupe fields. International Journal of Pest Management 40(1):50-55.

Schaber,B.D., Dormoor,J.F., and Entz, T.1993. effect of burning alfalfa stubble for insect control on seed yields. Journal of Entomological Society of British Columbia 90:41-45.

Seal, D.R., Chalfant, R.B., and Hall, M.R.1992. effects of cultural practices and rotational crops on abundance of wireworms (Coleoptera: Elateridae) affecting sweet potatoes in Georgia. Environmental Entomology 21(5): 969-974.

Seshu Reddy, K.V. 1985. Integrated approach to the control of sorghum stem borers. In Proc. Int. Sorghum Entomol. Workshop, 15-21, July, 1984. Texas A & M Univ. College Station, Texas, USA; International Crops Research Institute for the Semi Arid Tropics (ICRISAT), patancheru AP 502 324, India: pp.205-215.

Seshu Reddy, K.V. 1990. Cultural control of Chilo Spp. in Graminaceous crops. Insect Sci.Applic. 11(4-5):703-712.

Shanower,T.G., Das, V.S.R., and Pal, S.K. 1993. Atypical oviposition behavior in Helicoverpa armigera (Hubner). International Chickpea newsletter 28:16-17.

Sharma, H.C. 1985. Strategies for pest control in sorghum in India. Trop. Pest Manage 32:167-185.

Shivayogeswara, B., Mallikharjunaiah, H., Krishnaprasad, N.K., and Shetty,M.V.N. 1992. Integrated Management of Spodoptera litura F. (Noctuidae: Lepidoptera) in FCV tobacco fields. Tobacco Research 17(2):59-61.

Singh, T.V.K., Singh, K.M. and Singh, R.N. 1991A. Influence of intercropping I. Incidence of major pests in ground (Arachis hypogea Linn.). Indian J. Ent. 53(1):18-44.

Singh, T.V.K., Singh, K.M.and Singh, R.N. 1991b. Influence of intercropping II. Incidence of hemipteran and homopteran pests in groundnut. Indian J.Ent. 53(2):190-209.

Singh, T.V.K., Singh, K.M. and Singh, R.N. 1991. Impact of intercropping: Yields of groundnut. Indian Journal of Entomology. 53(3):369-372.

Singh, T.V.K., Singh, K.M., and Singh, R.N. 1991b. Influence of intercropping on the incidence of major pests of groundnut (Arachis Hypogaea Linn). Indian Journal of Entomology. 53(1):18-44.

Singh, T.V.K., Singh, K.M., and Singh, R.N. 1991c. Influence of intercropping: II. Incidence of hemiptern and homoptern pests in groundnut. Indian journal of Entomology 53(2):190-209.

Singla, M.L., Singh, B., Mahal,M.S. 1991. Influence of varieties and plant spacing on damage by Helicoverpa armigera (Hub) in gram. Journal of Insect science 4(1):95-96.

Slosser, J.E., Pinchak, W.E., and Frank, W.A. 1992. Effect of planting date on cotton aphid and bandedwinged whitefly populations in dryland cotton. Southwestern Entomologist 17(2): 89-100.

Smith, J.W. and Johnson, S.J. 1989. Natural mortality of the lesser cornstalk borer (Lepidoptera: Pyralidae) in a peanut agroecosystem. Environmental Entomology 18:69-77.

Srinivasan, K., Murthy, P.N.K., and Krishna Murthy, P.N. 1991. Mustard plant trap major cabbage pests. Indian Farming 40(11):11-12.

Srinivasan, K., Moorthy, P.N.K., and Ravi Prasad, T.N. 1994. African marigold as a trap crop for the management of the fruit borer Helicoverpa armigera on tomato. International Journal of Pest Management 40 (1): 56-63.

Thakur, R.C., Nema, K.K. and Singh, O.P. 1992. Present status of Helicoverpa armigera in pulses and strategies for its management in Madhya Pradesh. 55-63pp. In: Helicoverpa management: Current Status and Future Strategies (Ed. Sachan, J.N.), proceedings of First National Workshop held at Directorate of Pulses Research, Kanpur, India 30-31 Aug, 1990.

Thenissen, J., Booij, Schelling, G., and Noorlander, J. 1992. Intercropping white cabbage with clover. Bulletin OILB SROP 15(4): 104-114.

Tonhasca, A.Jr.1994. Response of soybean herbivores to two agronomic practices increasing agroecosystem diversity. Agriculture Ecosystem and Environment 48:57-65.

Vaithilingam, C., and Balasubramanian, M. 1978. Effect of potash nutrition on the amino acid content of rice in relation to pest control. Indian J.Plant Prot.6:27-30.

Varun, C.L., Suchitra Singh., Pandey, K.P., Singh, S.B., and Singh. S. 1994. Influence of companion cropping of spices on the incidence of early shoot borer (Chilo infuscatellus) in sugar cane. Indian Sugar 44(1):21-22.

Verma, A.N., and Singh, S.P. 1989. Cultural Control of Sorghum stem borers. In Proc. International workshop on Sorghum Stem Borers, 17-20 Nov.1987. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT),Patancheru, A.P. 502 324, India, pp.81-87.

Veeresh, G.K. 1977. Studies on the Root grubs in Karnataka. U.A.S.Monograph Series. University of Agricultural Sciences. Hebbal, Bangalore - 560 024.pp.87.

Yadav, R.P., Kumar, N., Singh, M.M., and Goel, S.C. 1992. Population dynamics of Bihar hairy caterpillar (Spilosoma obliqua Walker) and its parasitoid complex as influenced by intercroppings. Bioecology and control of insect pests: Proceedings of the National Symposium on Growth, Development & Control Technology of Insect Pests 225-231.

Webb,S.E., and Linda, S.B. 1992. Evaluation of spunbound polyethylene row cover as a method of excluding insect and viruses affecting fall-grown squash in Florida. Journal of economic entomology 85(6):2344-2352.

Wiech,K., and Wnuk, A. 1991. The effect of intercropping cabbage with white clover and french bean on the occurrence

of some pests and beneficial insects. Folia Horticulturae 3(1):39-45.

Wightman,J.A., and Ranga Rao,G.V. 1994. The Groundnut Crop. A scientific basis for improvement (Ed.Smartt, J.)Chapman & Hall, London. pp.395-479.

Wu,G., Chen, Z., Ji, M., Dong, S., Li, H., An,J., and Shi, J. 1991. Influence of interplanting corn in cotton fields on natural enemy population and its effect on pest control in southern Shaanxi. Chinese Journal of Biological control 7(3):101-104.

Yadav,C.P.S. 1981. Integrated control of white grub. Department of Entomology, University of Udaipur (at Jobner), Rajasthan, India. ix + 219 pp.

Yadav, C.P.S., and Sharma,G.K. 1995. Indian white grubs and their management. Technical Bulletin 2. (Project Coordinating Center, All India Coordinated Research Project on Whitegrubs, Agricultural Research Station, Durgapur, Jaipur), ICAR, Krishi Bhavan, New Delhi pp.26.

Zelarayan, E.L., Buntin, G.D., Johnson, J.W., Burkner, P.L., and Raymer, P.L. 1991. Integrated management for Hassian fly in triticale. Journal of Production Agriculture 4(4):629-632.