REVIEW OF LITERATURE

Altieri *et al* (1978) observed that in Colombia beans grown as maize / bean polycultures had 26 per cent fewer *Emposca kraemerii* Ross and Moore adults than monoculture beans. Similarly population of *Diabrotica baltecata* Le conte were 45 percent less in polycultures. *Spodoptera frugiperda* (Smith) incidence as cutworm in maize was reduced by 14 per cent in polycultures. Also these systems had 23 per cent less infestation of fall army worm as whorl feeder. Maize planted 30 and 20 days earlier than beans reduced leaf hoppers on beans by 66 per cent as compared to simultaneous planting, similarly fall army worm damage was reduced by 88 per cent when beans were planted 20-40 days earlier than maize.

Al-Musa (1982) observed that whiteflies were more attractive to cucumber than tomato but was not a host of TYLCV (Tomato yellow leaf curl virus) in Jordan. Cucumber (*Cucumis sativus*; Cucurbitaceae) as a trap crop between rows of tomato, substantially decreased the incidence of TYLCV. To avoid massive movement of whitefly adults, cucumbers were treated with insecticide before senescence.

Altieri and Gilesman (1983) observed that populations of flea beetle, *Phyllotreta cruciferae* Goeze (Coleoptera: Chrysomelidae) were greater in weed free collards than in collard monocultures and polycultures (intercropped with beans). Flea beetle densities and amount of leaf damage per plant were significantly lower in plots with crucifer weeds mainly *Brassica campestris* L. possibly the beetles preferred this plants than collards.

Andow and Altieri (1983) reported that research involving 198 kinds of insects revealed that intercropping led to a reduction in insect pest populations in 53% of
all insect / crop combinations, an increase in 18% of combinations, no effect in 9% and variable response in 20%.

Amoako et al. (1983) found that the presence of Maize and Cowpea crops within the cotton system enabled establishment of high population of beneficial insects in cotton field on time prior to the arrival of aphids, whitefly and Helicoverpa Spp. Lower insect attack maximized yields up to 331 kg/ha in dry land conditions.

Andow and Risch (1985) opined that a common prediction based on ecological theory was that natural populations of insect predators will be more abundant and effective in diverse plant assemblages. In their experiment the abundance of the predaceous Coccinellid beetle, Coleomegilla maculata (DeGeer), (Coleoptera : Coccinellidae) was higher on corn in monocultures than on corn in two different polycultures. In addition, predation rate by the beetle on egg masses of the European corn borer, Ostrinia nubilalis (Walker) was higher in monocultures. The higher density of evenly spaced food rewards in the form of abundant prey and corn pollen in the corn monocultures had the greatest impact on the beetle behavior resulting in decreased emigration. If the diversification results in a greater abundance of resources are more even spatial dispersion of food, then predators can be made more abundant and effective in diversified agro ecosystems.

Andow and Risch (1987) observed that in maize – bare ground monocultures and polycultures of maize / bean / squash and maize / clover, parasitism rates by Trichogramma minutum were 1.9 times higher in monocultures than in polycultures. Parasitism was affected by predation of eggs of Ostrinia nubilalis egg masses in polycultures. In late season parasitism decreased in both situations.
Altieri (1990) in his field studies conducted in Colombia and Florida involving the fall army worm (FAW), *Spdoptera frugiperda* (J.E. Smith), its damage, larval parasitism, predator abundance and crop yields in different corn cropping systems suggested that there was great potential for manipulating plant diversity within crop systems to provide additional safe guards against pest insects.

Abate (1991) studied effects of strip cropping in haricot bean, *Phaseolus vulgaris* L. with maize (*Zea mays* L.) under weeded and unweeded conditions on the abundance of tachinid parasites and predatory wasps, *Tiphia sp* associated with African bollworm. Tachinids were more abundant in strip cropped and weedy plots than in monoculture. Strip cropping had no effect on *Tiphia sp* numbers whereas the wasp was 2-8 times more abundant in weedy than in weed free plots.

Ameen and Hasabo (1995) found that intercropping of *Asparagus scandens* with sour orange seedlings, *Citrus aurantium* gave significant reduction on *Tylenchulus semipenetrans* larvae in soil and it was attributed to toxic effect of root exudates of A. *scandens*.

Ahoehundo and Sarkar (1995) used maize as intercrop in cassava to partially control *Bemisia tabaci* movement. The revealed the effectiveness of maize as barrier crop to reduce whitefly immigration.

Asman *et al.* (2001) observed that red clover in *Allium* spp. and cabbage as intercrop did not appear to affect the emigration of either the leek moth or the diamond back moth. However, it was concluded that the diamond back moth may likely to be controlled by intercropping than leek moth.
Alston and Drost (2008) reported that intercropping or mixed planting of carrots and onions have shown to reduce onion thrips population on onions by attracting them to carrots. Thrips injury was tolerated by carrots without yield loss.

Asewar et al. (2008) reported that among intercropping systems, cotton + green gram was significantly superior over cotton + soybean and cotton + black gram. Burleigh et al. (1973) observed that larger number of beneficial insects were found in cotton growing immediately adjacent to sorghum than cotton grown distal to this strip crop. The cotton – corn exhibited the reverse effect. Lady beetles, *Hippodamia* sp. were one of the main predators in cotton adjacent to sorghum. Parasitism of *H.zea* was up to 26.3 per cent. Lady beetles exhibited significant increase in population during late season, while others decline as the season progressed.

Brust et al. (1986) reported that in a trial maize was intercropped into grass legume mixtures and compared to monoculture maize to evaluate effects of intercropping on macro arthropod predator activity. It was observed that the predation was higher in intercropped system compared with monoculture. Carabid beetles and spiders were the major predators. It was concluded that predator activity was significant factor in reducing pest population in intercropped agro ecosystems.

Bhagwat et al. (1994) recorded lesser incidence of natural enemy *Gyron sp* on *Clavigralla* in pigeonpea intercropped with cotton, than in sole pigeon pea.

Balasubramanian et al. (1998) observed low incidence of leaf hoppers, aphids, thrips and whiteflies in cotton intercropped with cluster bean or green gram. They also observed that more population of spiders in cotton intercropped with cluster
bean than in cotton monocrop. They further observed higher incidence of Coccinellid lady bird beetles in cotton intercropped with cowpea than in monocrop of cotton.

Brevault et al. (2009) mentioned that leguminous soil cover harboured more individuals than tilled soil, particularly earth worms (Lambricidae), millipedes (Julidae), Lexapods (Japigidae and Lepsimatidae), centipedes (Scolopendridae) and spiders. Graminaceous soil cover was surprisingly poorer in chilopods and earthworms, but harbored more carabids. Detrivore millipedes may become phytophagous when their food sources were depleted. They were mostly numerous in soil cover mulches that provide favorable habitat.

Balakrishnan et al. (2010) reported that due to trap crops and intercrops, incidence of sucking pests and pod borers in cotton has been reduced in different IPM modules validated in Tamil Nadu.

Chakravarthy et al. (1997) reported that increased parasitism might be due to the availability of nectar, pollen and existence of favorable microclimate in intercropped zones of agro – ecosystem and increased natural enemies viz., Coccinellids and Chrysopids by conservation.

Corbett and Plants (1993) constructed a simulation model for the response of natural enemies to interplanted strip vegetation. They suggested that interplanted vegetation acts as a source of natural enemies when they colonize strip vegetation before germination of the main crop. However, it acts as a sink when the main crop and interplanted vegetation germinate simultaneously. Variability may be caused by an interaction between natural enemy movement and system design rather than fundamental difference in natural enemy behavior.
Cederbaum et al. (2004) observed that new cropping approaches, such as use of conservation tillage and strip cover cropping, offer hope for improving the ecological value of cotton fields. Clover as strip cover and conservation tillage vs conventional tillage and cotton cultivation were monitored for bird and arthropod activity in Georgia cotton fields. Strip cover fields had higher bird densities, biomass and higher relative abundance of arthropods than both conservation tillage and conventional fields. Bird density were 2 to 6 times and 7 to 20 times greater in strip cover fields than in conservation tillage and conventional fields, respectively. Finding suggests that both conservation tillage and strip cropping systems will improve conditions for birds and arthropods in cotton with strip cropped fields providing superior habitat. There was an input reduction to the extent of $282 – 317/ha over conventional cotton fields by strip cover cropping.

Chamuene et al. (2007) reported that sorghum, Sorghum bicolor L pigeonpea, Cajanus cajan and Crotalaria ochroleuca strip intercropped with cotton had fewer H.armigera and A.gossypii infested plants and contained abundant population of natural enemies like syrphids, green lacewings and spiders.

Central Institute for Cotton Research (2010) reported that major cropping systems (intercropping) in Maharashtra cotton were cotton + green gram – black gram (1:1), cotton + sorghum + pigeonpea + sorghum (6:1:2:1 row proportion).

Cotton Corporation of India (2010) reported that cotton occupied about 8.78 million hectares with a production of 243 lakh bales during 2004-2005. Major cotton growing states were Maharashtra, Gujarat, Andhra Pradesh and Haryana. In Andhra Pradesh it was grown in 1.17 million hectares with a productivity 469 kg/ha of
seed cotton. While the national productivity was also 470 kg/ha (Cotton Corporation of India, 2010).

Duncan (1955) developed multiple range test which involves the computation of numerical boundaries that allow the classification of differences between any two means as significant or non significant.

Dhuri et al. (1986) in their study on intercropping black gram with green gram, pigeonpea, sesame and sorghum found that change in crop canopy brought about by intercropping had considerable impact on buildup of insect pest in black gram. Intercropping green gram with black gram favored pests in black gram, whereas intercropping with sorghum or pigeonpea pest buildup was slow and predator activity was enhanced.

Dhaliwal et al. (1997) found no effect on insect pests of cotton, when intercropped with Okra and also with barrier crops of pigeonpea or pearl millet. The study revealed that in selecting inter crops it is necessary that they are not hosts or poor hosts of the insect pests of main crop.

Den Belder et al. (2000) reported increased damage by flower thrips in chrysanthemums intercropped with subterranean clover.

Deguine (2007) observed that biological agricultural systems in cotton (BASIC) were in operation in California for 12 years or so and illustrated a possible method for transition from traditional IPM towards a true biological production system, which encompasses intercropping.

Dhawan and Harith K. Bal (2008) in their studies on the population of key pests and natural enemies in RCH 134 Bt and non-Bt cotton hybrid under sprayed
and unsprayed condition under intercropped situations revealed that significantly lower incidence of spotted bollworms in cotton with intercrops like okra, pigeonpea, castor and cowpea.

Department of Agriculture and Co-operation (2010) reported that the pesticide consumption in India was 48,860 MT during 2008-09, out of which 1015 MT was in Andhra Pradesh.

Evan and Dixon (1986) established in a laboratory study that cues for oviposition of lady beetles were aphid odours and aphid honey dew. It was understood that inter crops also need to attract pest species to enhance natural enemy activity. However, the pest species involved should not be a host of the main crop. The observations in the study highlights the importance of certain weed species in insect pest/natural enemy/host plant interactions.

Ellsworth et al. (1992) observed that the either weed, Physalis wrightii or melon when intercropped with cotton acted as trap crops for whiteflies.

Elanchezhyan et al. (2008) evaluated thirteen crops as intercrops in brinjal and found that population of natural enemies like coccinellids, syrphids and spiders were high in brinjal intercropped with cluster bean, recording 4.3, 3.1 and 1.9 number per plant, respectively as compared to brinjal pure crop. Damage by fruit borer, Leucinodes orbonalis and whiteflies, Bemisia tabaci were very low and also less incidence of Aphis gossypii in intercropped brinjal.

Ferguson et al. (1984a) identified five dominant spider families on Virginia soybeans, two on the ground (Lycosidae and Linyphiidae) and three on the foliage (Oxyopidae, Thomisidae and Salticidae). Higher spider populations were
collected from foliage in soybeans double cropped after barley harvest and in full season soybeans that were drill-planted. The ground spiders were numerous in both barley and wheat-soybean double-cropped systems. Further, Ferguson et al. (1984b) found that among the foliage inhabiting predators, *Orius insidiosus* (Say) was the most abundant insect predator followed by *Nabis roseipennis* Reuter and *Geocoris* spp. Total predator counts on the foliage were highest in August and early September. Coccinellids were numerous in double-cropped barley-bean and drill-planted fields.

Flint and Roberts (1988) observed that moderate and small scale cotton growers in California adopt crop rotation. Crop rotation was successful in reducing sugar beet cyst and root knot nematode problems. Intercropping cotton with alfalfa and oats as companion plants reduced pest infestation. It was shown that crop diversification to manage pests was feasible but growers must be motivated to make necessary changes in cropping pattern.

Fabiao and De Souza (2007) reported that strip intercropping of cotton with maize reduced sucking pest incidence in cotton and enhanced natural enemy activity. Garcia et al. (1997) observed changes in species assemblages of predatory Coccinellids in response to landscape structures (habitat diversity and patchiness) in southern Michigan landscape with alfalfa, corn, wheat mosaics. Of the 13 species of coccinellids captured, *Coccinella septempunctata* was more dominant and is equally abundant in all the mosaics. *Coleomegilla maculata lengi* Timberlake was more abundant in corn habitats where as *Cycloneda munda* (Say), *Chilocorus stigma* (Say) *Brachiacantha ursina* F. were more abundant in deciduous habitat. The presence of uncultivated habitat contributed to species richness.
Girma et al. (2004) studied the effect of nine hedge row plant species on the abundance of major insect pests of beans, maize and predatory / parasitic – arthropods and reported that hedge rows did not influence aphid, *Aphis fabae* infestation on beans. In contrast maize associated with hedgerow experienced significantly lower stalk borers, *Busseola fusca* and *Chilo spp.* and aphids, *Rhopalosiphum maidis* infestations than pure maize. The margin of difference being 13 and 11 per cent, respectively for the two pests. Activity of ladybird beetles and wasps was significantly greater in maize close to hedgerows. Spider catches during maize seasons were 77 per cent greater in the presence of hedgerows than in their absence.

Gao et al. (2008) studied the effects of insecticides on the structural productivity of insect pests and natural enemy communities in Hebei province in China and reported that intercropped cotton showed higher number of natural enemies and insect pests with slower buildup of insecticide resistance. The importance of insecticide susceptible insect pest population on intercrops in reducing the resistance buildup was emphasized in this study.

Horowitz (1986) reported that higher number of nymphs, adults and eggs of whitefly were recorded at higher temperatures in cotton fields, whereas rainfall was negatively correlated with whitefly adult population.

Hirano et al. (1995) reported that one of the major factors responsible for whitefly population dynamics seems to be temporal variation in the quantity of host plants in the area. The study suggested that monocultures tend to increase the buildup of whiteflies, whereas diverse crop cultures slow down the build up.
Hooks and Johnson (2002) compared the preference of broccoli, *Brassica oleracea* var. *italica* L., intercropped with tomato or yellow sweetclover and its monoculture. It revealed that incidence of cabbage worm, *Artogeia rapae* L., was greater in monoculture compared with intercropped plantings. The mean percentage of broccoli heads infested with insects and associated frass were higher in monocultures than in intercropped crops.

Hummel *et al.* (2002) observed populations of epigeal arthropods in vegetable production system viz., two tillage types (Plough, disk and strip tillage), two input approaches (chemical and biological) and two cropping schedules (continuous tomato, 3-year rotation of sweet corn – cabbage – cucumbers). Pitfall trap data revealed that carabids and lycosids were more active in systems with ground cover. Carabids were not affected by insecticide use but lycosids were significantly low in insecticide used plots. Ground cover enhanced abundance of carabids and lycosids while tillage type, pesticide use and crop rotation had different effects.

Hegde *et al.* (2003) observed that *Chrysoperla carnea* and *Trichogramma* were conserved due to intercropping grain sorghum in cotton. The predation and parasitization rates increased respectively due to the two bio agents as a result *Helicoverpa armigera* could be brought to below ET levels in cotton.

Hanumantharaya *et al.* (2008) made an attempt for the management of cotton pests, cv.DCH-543 by biocontrol agents, botanicals and intercrop. The results revealed that intercrop with lucern (1:1 row population), two sprays of NSKE (5%) on cotton at 38 and 60 DAS and release of *C.carnea* (Stephens) grubs @ 0.75 and 1.0 lakh/ha resulted in almost doubling of yields compared to untreated check.
Harisudan et al. (2009) observed cotton being a long duration and wide spaced crop having the habit of growing at slower rate in early stages and much of vacant interspace remains unutilized. It was indeed worthy to use the land fully well by resorting to introduction of intercrops. It has unique capacity to raise unit profitability without unduly disturbing the cotton eco system. Intercropping legumes (Black gram) was an important aspect for biological farming systems not only for weed control but also reducing the leaching of nutrients, pest control and soil erosion.

Hormchan et al. (2009) laid out a trial with white and natural colored cotton of 4 varieties/lines, each was cultivated in monoculture and with perimeter trap cropping and row intercropping with okra and castor bean. The plots with trap crops were found to decrease in leafhopper population with increased yields as compared to the sole cotton in every variety/line.

Jambhrunkar et al. (1998) found that intercropping cotton with legumes reduced the incidence of Bemisia tabaci and Amsacta biguttula, the most important sucking pests of cotton.

Jones and Gillett (2005) in two years of study at a number of organic farms in Alachua County, Florida to determine the influence of sunflower rows in poly culture system on abundance of beneficials in cropped fields revealed that sunflower attracts and plays host to numerous beneficial insects suggesting that sunflower planting within the rows of vegetable crops may indeed be an effective way to attract beneficial insects into cropped fields.
Jackson (2005) observed that in Kutch, Gujarat (India) intercrops such as soybean, cowpea, watermelon or sweet melon in 1:1 ratio, also green gram, black gram and sesame in cotton reduced infestation of jassids, aphids and thrips. The appearance of jassids started in July – August and continued till October - November and that of aphids in August and disappeared. Later the activity of aphids started in October – November and continued till end of the season. Thrips were active in only August on young cotton plants.

Johnson et al. (2006) showed that mere presence of the predator, Geocoris lubra on a plant can have a strong influence on the movement and behavior of H.armigera. Predators not only reduce the numbers of herbivores but also influence feeding, displacement and subsequently the distribution of the pest in the plant canopy.

Jayakumar et al. (2008) in their experiment of five intercropping systems viz., cotton + onion, cotton + black gram, cotton + green gram, cotton + lucerne grown under inorganic and organic source of nitrogen recorded significantly low incidence of pests in inter cropped cotton than cotton monocrop. Organically grown and intercropped cotton recorded lesser incidence of pest and higher abundance of natural enemies than inorganically grown cotton.

Kochler (1992) observed that soil meso fauna were involved in processing organic matter and augmenting processes involved in soil structure. Spring tails (Collembola) were the prey of many arthropods particularly beetles and predatory communities and there by form a fundamental element of tropic interactions. Cotton leaf litter supported better diversity of spring tails than maize leaf litter.
Kulandaivel et al. (2009) showed that high density of cotton under paired planting with black gram recorded the highest seed cotton yield. Black gram resulted in higher economic return and land equivalent ratio than cotton. Cotton grown with either black gram or onion as intercrop had higher returns than sole crop.

Khan et al (2008) reported that in field grown cotton, population increase of thrips was positively correlated with high humidity and negatively with red spider mites population.

Kranthi and Russell (2009) in their review of changing trends in cotton pest management mentioned about the lady beetles and lacewings as important predators in cotton intercropped with different pulse crops.

Laster and Furr (1972) noted that sesame attractiveness to Heliothis and sesame’s ability to harbour high number of beneficial insects made it useful in a cotton pest management program.

Lin et al. (2003) studied the intercropping of cotton mainly with alfalfa. In spring alfalfa was cut and some predators were obliged to migrate into cotton fields, the results indicated that the increment of population of cotton aphids was significantly slower in cotton grown in plots which bordered the alfalfa cutting areas than in uncut control, while the rate of increase of spiders and lace wings were significantly faster in cotton grown in plots bordering the cut areas than in uncut plots. Leite et al. (2005) observed that plant pubescence and natural enemies, mainly Encarsia sp., Chrysoperla spp and coccinellids were some of the factors that mostly contributed to whitefly reduction in okra plantations. Higher number of whitefly nymphs were found on the middle part than on the bottom part. Leonard et al. (2010) found that the physical
attractiveness of plants as well as residues from native vegetation of previous crops has been shown to influence insect population dynamics.

Liu et al. (2010) found that ground dwelling carabids (Coleoptera: Carabidae) are important in regulating the soil inhabiting life stages of foliar insects of cotton. Diverse habitats and diversity of cropping system were proposed as promoters of ground beetle diversity in intensely managed agricultural crops like cotton, maize and wheat.

Marcovitch (1935) observed the increasing effectiveness of natural enemies of plant lice when corn, and cotton were intercropped with peas and cantaloupes. The main crops were practically free from aphids while pure stands planted on the same dates, just 120 yards away were destroyed.

Muruganandam (1984) proposed that short maturing pulses like black gram, green gram and cluster bean can be intercropped with cotton advantageously. The experiment resulted in lesser incidence of insect pests with higher cotton yields and better economic returns.

Marino and Landis (1996) noticed that rates of parasitism of army worm larvae were higher in complex agricultural landscapes than in simple landscapes. The richness and rates of larval parasitization of armyworm Pseudaletia unipunctata in maize were compared with monoculture fields and fields embedded in complex landscapes with abundant hedgerows and wood lots. Parasitoid species diversity did not differ significantly in both landscapes but mean per cent parasitism was significantly higher in complex landscapes than in simple landscapes (13.1% vs 2.4%) but was not affected by the location within the field (near or farther to hedgerows).
Mensah (1999) in his study on habitat diversity and implications for the conservation and use of predatory insects of *Helicoverpa* spp, observed the utility of crops such as sunflower, *Helianthus annuus*, safflower, *Carthamus tinctorius*, Lucerne, *Medicago sativa* and tomato, *Licopersicum esculentum* as refugia for predatory insects of *Helicoverpa* spp. When they were planted as strip crops in cotton fields indicated that lucern contributed effectively to the abundance of predatory beetles, bugs and lacewings than any other crop. He concluded that 2.1, 2.5, 1.2 times more predatory beetles, bugs and lace wings per meter row were recorded on cotton with strip crops than without.

Ma *et al.* (2006) reported that aphids were significantly low in cotton intercropped with wheat susceptible to the cereal aphids than resistant wheat due to abundance of natural enemies within wheat which served as over wintering sites after harvest for aphid natural enemies. It was concluded that insect susceptible inter crops attract more natural enemies than resistance ones. However, the pest should be species not attacking the main crop.

Mohapatra (2008) observed three major sucking pests viz., leaf hopper, aphids and whitefly infestation in cotton from 30th to 50th standard week. Peak population of the three pest was attained during 41st standard week (October 8-14), 44th standard week (October 29th to November 4th) and 35th standard week (August 27th to September 2nd) respectively.

Natarajan and Seshadri (1988) observed that cotton when intercropped with soybean contained higher number of natural enemies than cotton alone.
Oestman et al. (2001) observed that landscape features themselves can influence the physiological condition of insects including carabid beetles. It was clear that the physiological condition of the insect was both a product of landscape structure and a factor that influences responses to fragmentations. Because of the diversity in landscape structure brought by intercropping that carabid population are conserved.

Pimental et al. (1980) in their status report on environmental and social costs of pesticides use were estimated at $8 billion per year in USA alone. The degradation of environment and financial burden on the farmers could be brought down by introducing diversified systems in agricultures.

Potdar et al. (1994) observed that advantageous economic returns from pigeon pea /cotton strip intercropping rotation in vertisols was mainly due to enhancement of soil fertility by legume intercrops and reduction of pest incidence due to increased natural enemy activity.

Parajulee and Slosser (1999) observed that among the eight relay strip crops viz., Canola, Brassica rapa L., Vicia villosa Roth, Triticum aestivum L. evaluated for enhancement of predators in cotton, it was concluded that over all strip crops significantly enhanced predator numbers in adjacent cotton plots. Average aphid abundance in cotton were significantly affected by adjacent strip crops compared to cotton monocrop. Severe bollworm attack was observed in adjacent cotton without strip crops where as in cotton with strip crops it was below economic threshold level. Average yields were higher in strip crop treatments than where it was not taken. Relay strip crops / inter crop systems could effectively reduce aphid population in cotton.
Prasifica et al. (2004) observed that the generalist predatory fauna was most often neither diverse nor abundant in agro ecosystems stripped off of their wild surroundings and it was for this reason crop diversification as a cultural technique in cotton cultivation was generally promoted in order to favour populations of beneficials and so as to reduce the need for repeated insecticidal treatments.

Perrin and Philips (2006) reported that mixed or intercropping of plant species and cultivars were a common cultural practice in many countries and amongst its potential advantages are effects on the population dynamics of pests, which may minimize crop damage.

Poveda et al. (2008) in their review of research papers on crop diversification in monocultures reported that out of 62 detailed reviews of original studies of last 10 years showed that diversification practices (a) enhance natural enemies in 52% (b) reduce pest pressure in 53% (c) increased yield in only 32% of the cases.

Prerna et al. (2008) observed that in cotton intercropped with green gram, black gram, cowpea, sorghum, maize, marigold and soybean in 1:1 ratio, cotton + cowpea proved to be the best by recording least population of spotted, pink and American bollworms as against sole crop with 60% higher yields than sole crop.

Pesticide Post (2009) reported that in Central and Southern India intercropping of cotton with black gram, green gram and cowpea was aimed to divert the population of sucking pest and American bollworm from cotton and helped colonization of coccinellids and enhanced parasitization of spotted bollworm mostly on cowpea. Intercropping groundnut with pearl millet reduced the incidence of thrips, jassids and leaf miner. It could be inferred from the study that pulse crops as inter crops reduced
bollworm attack and cereal and oil seed crops brought down certain pests. Thus in intercropping systems greater diversity of crops was required. Crops like cotton with multiple economically important insectry pests.

Phoofofo et al. (2010) reported that low infestation levels of aphids in the intercrops and high incidence of corn leaf aphids on main crop sorghum resulted in lack of significant effects of relay intercropping on lady beetle population.

Rajarathinam et al. (1996) reported that cotton when intercropped with black gram showed lesser incidence of sucking pests. The presence of non host plants surrounding the host plant canopy could be a factor in reduction of sucking pests of cotton.

Raemert et al. (2001) reported that mulching of agricultural fields in southern Sweden increased the densities of Staphylinid beetles. Intercropping due to its addition of crop residue (leaf litter) was favorable for predatory soil dwelling arthropods.


Rathod and Bapodra (2004) reported that aphids initiated in cotton from July and remained active during October – December with highest activity in last week of November. Coccinellid predators showed density dependent fluctuations with their host, the aphid.

Ravi et al. (2005) in their study on relative abundance of *H.armigera* on different host crops within a crop mosaic found that eggs and larvae were significantly higher on pigeonpea and chickpea than on cotton and other host crops. Eggs were high
on sunflower, okra and tomato than on cotton. Both eggs and larval numbers on corn and chilli were comparable as those on cotton. The study demonstrated number of host crops of *H.armigera* support large populations at the same time that cotton was infested. These crops may act as important sources of refuge for natural enemies and *Bacillus thuringiensis* on cotton in Central and Southern India.

Rajeswaran *et al.* (2005) in a review of cotton ecosystem reported that the cotton ecosystem includes a wide variety of arthropods throughout the world. More than 1326 species of insects have been reported attacking cotton in the world. In India, 162 species have been recorded among which only 15 species considered potential threat to the crop. In cotton ecosystem 21 species of spiders grouped under 16 genera belonging to 8 families were reported. The predatory potential of *Paradosa viridanum* was maximum on sucking pests of cotton.

Adult stages of predators and parasites derived supplemental nutrition from nectar and pollen from the vegetation and their members flourished in high densities with floral diversity. Whereas the pre imaginal stages require presence of insect hosts and the observations of Rana (2006) showed that lady bird beetle eggs population initiated four to five weeks before maximum aphid infestation in mustard. Egg and larval densities were positively correlated with aphid numbers while adult beetle activity were not influenced by aphid numbers.

Reddy *et al.* (2006) observed when chilli was intercropped with either brinjal, bhendi, garlic, onion, marigold, maize or beans, the sucking pest of chilli crop were low compared to monoculture of chilli crop.
Singh and Singh (1978) observed that the two major impacts noticed in all the intercropping combinations were, a delay in the appearance and lower level of incidence of sucking pests in pigeon pea and provision of better niches for the activity of spiders throughout. They also reported that maximum reduction of 33 – 75 per cent incidence of jassids took place when red gram was intercropped with pearl millet. Intercropping with sorghum and pearl millet reduced green stink bug, pod borer and pod fly infestation to an extent of 45 – 96 percent with pearl millet intercropped with red gram.

Seshadri and Natarajan (1989) observed that shedding of fruiting parts in cotton caused by insects attack was significantly low in the plots intercropped with cowpea (91/plot) and soybean (88/plot) and nearly significantly low in the plots intercropped with onion compared with plots with no intercrop (118/plot) This indicated the incidence of cotton bollworms could be reduced through intercropping.

Sansone and Smith (2001) in their study on mortality factors of *H. zea* in short season cotton found that *Orius insidiosus* (Say), a Geocorid bug was a predominant predator causing 84 and 71 per cent mortality of eggs in 1994 and 95, respectively and larval parasitization rarely exceeded 5 per cent, thus they conclude that predators were more important mortality factors of *H. zea* than parasites.

Srinivasa Rao (2001) observed that the intercropping had positive influence and SD (short duration) pigeon pea – Sorghum / SD Pageonpea / castor di-crop combination reduced infestation of majority of pests. Sansone and Smith (2001) in their study on life table of *H. zea* (Boisd) on cotton in Texas observed that 93 to 99 per cent mortality was observed at egg and first-instar life stages. Egg parasitization by
Trichogramma spp averaged 3.4 per cent, larval parasitization by Microplitis croceipes (Cresson) averaged 5 per cent., Orius insidiosus (Say) was dominant predator consuming 84 – 71 percent eggs of H.zea.

Smith et al. (2001) reported that intercropping in common bean, Phaseolus vulgaris L with poor and non-hosts did not reduce whitefly density on bean in an economically significant manner under high, intermediate or low whitefly population levels either in dry or rainy season.

Sharma and Singh (2002) in a study of preference of host plants by bhendi green leaf hopper, Empoasca sp. found that green gram, shoe flower and Portia tree were rejected by the hopper, whereas red gram, sesame, cotton, cowpea and eggplant were preferred. It was also observed that leaf-vein thickness and length were crucial factors in influencing the oviposition behaviour of cotton leaf hopper. It could be inferred from the study that due to intercropping of, incidence of leaf hopper in cotton might be high.

Sreekanth et al. (2002) reported that thrips caused about 40 per cent yield loss in green gram. Intercropping with peanut, sorghum and maize recorded reduction in thrips population by 71, 62 and 57 per cent (in Rabi season) and 69, 62 and 60 per cent reduction in Kharif season.

Swaminathan et al. (2002) found that in southern part of Tamil Nadu (India) at three locations, when jassids population was monitored at weekly intervals in six cotton intercropping systems namely cotton + cowpea, cotton + black gram, cotton + green gram, cotton + sunflower, cotton + sorghum and cotton alone, maximum population was observed in cotton + sunflower intercropping and minimum in cotton + cowpea, cotton + black gram and cotton + green gram during rainy season.
Showler and Greenberg (2003) in their study observed that in weedy and weed free cotton, *Gossypium hirsutum* L. plots, prey and predator ratios were 1:1.2 and 1:1.4 in weed free and weedy cotton plots. Boll weevil populations were not effected by the treatments.

Scholz and Parker (2004) found that intercropping cotton with sorghum encouraged the establishment and population growth of *Trichogramma* and two species of predatory beetles in cotton. Inoculative releases of *Trichogramma* were able to establish the parasite in cotton intercropped with sorghum better than in cotton alone. Predatory beetles moved from sorghum to cotton.

Sastawa *et al.* (2005) observed that in four intercrops pattern (3:1, 2:1, 1:1 and 0:1) of millet to groundnut and two intercrops system of millet - groundnut (MG) and millet - groundnut – soybean – cowpea (MGCS), aphid numbers and their predator (*Cheilomenes vicina*) numbers were not significantly correlated. Expected and observed proportions of groundnut plants infested by aphids were not significant over two cropping seasons.

Sarker *et al.* (2007) observed that the weekly aphid population of *Lipaphis erysimi* (Kaltenbach) in garlic and onion intercropped mustard was significantly low as compared to sole crop of mustard. Mustard intercropped with garlic showed highest cost benefit ratio (1:2.07 and 1:2.96) in 2005 – 07.

Sree Rekha *et al.* (2008) conducted an experiment in 1:1 ratio of soybean, green gram, black gram and cowpea intercropped with cotton and concluded that cotton + soybean and cotton +green gram were more remunerative with 14 – 15% more productivity.
Sharma et al. (2009) revealed that interplant maize / cowpea acted as source of predator due to diverse microhabitats, greater availability of food sources such as prey, nectar and pollen, all of which encouraged colonization and build up of natural enemies, compared with cotton monoculture having lesser biodiversity.

Sankaranarayanan, (2009) observed that there was no change in sucking pest complex , when cotton was intercropped with vegetables like radish, cluster bean and beet root.

Surulivelu (2009) reported that intercropping with black gram and chillies reduced the intensity of bollworms infestation in cotton.

Theunissen and Den Ouden (1980) in their intercropping experiments of Brussles sprouts with Spergula arvensis showed a significant pest reducing effect. *Mamestra brassicae* and *Evergestis forficalis* populations showed a strong reduction, whereas *Pieris rapae* did not responded to intercropping. Late cabbage root fly infestation on sprouted buttons was reduced drastically.

Tingey and Lamont (1988) observed that densities of four herbivorous insect species in field beans, *Phaseolus vulgaris* grown in monoculture and those grown in relay intercropping with winter wheat, incidence of *Empoasca fabae* (Harris) and *Aphis fabae* (Scopoli) were significantly low in intercropped field beans.

Trenbath (1993) in his review expressed that components of intercrops were often less damaged by pest and disease organisms than in sole crops.

Tonhasca (1993) compared the performance of corn, soybean as monoculture and strip intercropping of corn and soybean under tillage system, no-tillage and conventional tillage. The results revealed that most of the foliage-inhabiting natural
enemies were significantly more abundant in intercropping than in monoculture plots, whereas soil-inhabiting natural enemies had higher numbers in no-tillage plots than in conventional tillage plots. Corn in intercropping plots provided shade, reduced wind speed, abundant alternate food and possibly higher humidity and lower temperatures for soybean natural enemies. A similar effect was likely caused by the stubble and weeds in no-tillage plots.

Torres and Ruberson (2005) monitored ground dwelling predatory arthropods in three pairs of commercial Bt and non-Bt cotton fields (5-15 ha) during three successive seasons using three sampling methods viz., bagged whole plants, drop cloth samples and pit fall traps. Insecticide was applied when ETL exceeded. Significantly lesser taxa of *Hippodamia convergens* were found in Bt cotton where as four taxa were recorded in non-Bt cotton. Abundance of ground dwelling predators was not affected by cotton type, whereas abundance of canopy predators varied across seasons with no population trend for either cotton type. Bt cotton had no negative impact on predator populations.

Thiunissen (2006) reported that plant volatiles released by non host plants intercropped in field vegetables decreased infestation of aphids in base crops.

Vieria et al. (1983) in their studies in Brazil showed that infestation of semi-perennial cotton *Gossypium hirsutum* by *Aphis gossypii* was about 14 times lower when the crop was intercropped with maize and cowpea, *Vigna unguiculata* than when it was grown as monoculture.
Venkatesan et al. (1987) observed that the population of leaf hopper was significantly low in cotton. However, when intercropped with sunflower, green gram and black gram, cotton + green gram recorded the highest gross income. Venugopala Rao et al. (1995) observed low incidence of *Helicoverpa armigera* in cotton intercropped with cluster bean and cowpea and enhanced abundance of natural enemies.

Van Den Berg and Cock (1995) observed irreplaceable mortality of *H. armigera* due to natural enemies in cotton in western Kenya due to ants, the predominant crawling predators, whereas anthocorids were predominant flying predators. Vaiyapuri et al. (2007) observed that intercropping with marigold in two rows in between cotton rows and incorporating it on 30 days after sowing of cotton had contributed ultimately to lower incidence of pests, more kapas and unit yield of cotton. Sann hemp and Sesamum had moderate and low effects, respectively on pest management.

Willey and Osiru (1972) proposed the concept of Land Equivalent Ratio (LER) which was the total land area required under sole cropping to give the yields obtained in the intercropping.

Wells et al. (2001) reported that densities of coccinellids in cotton closely tracked the aphid population, suggesting that coccinellid predators were more density dependent.

Witmer et al. (2003) found that ground-dwelling arthropods sampled in corn, soybean and wheat cropping systems in mid-Atlantic region of United States mostly contained Carabids and spiders. Overall beneficial arthropod populations were lowest, whereas corn insect pest population especially western corn root worms, *Diabrotica virgifera* (Le Conte) were highest in the simplest, most intensively managed continuous
corn system, which had annual use of soil insecticides. Generally ground-dwelling species were higher in soybeans than in corn and similarly in no-till than in deep-tilled crops.

Wu and Guo (2005) in their study on risk assessment analysis of Bt cotton in China observed that the natural refuges derived from mixed planting system of cotton, corn, soybean and peanut on small scale single family owned farmers played an important role in delaying evaluation of cotton bollworm resistance and despite intensive cultivation of Bt cotton over several years resistance in bollworm, *Helicoverpa armigera* was not noticed.

Yelshetty *et al.* (2009) reported that pigeonpea intercropped with soybean had lesser incidence of *H.armigera* compared to pigeonpea + cotton, pigeonpea + groundnut and pigeonpea + green gram.