



Conservation Agriculture for the management of insect pests- A review

Shamik Dey*, Krishna Karmakar

Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India

Abstract

Declining in soil health condition through conventional agriculture system is a serious worldwide problem that not only decreases sustainability and stability of agricultural ecosystems but commonly making them more prone to outbreaks of different herbivorous insect pests in different field crops and vegetables production which are currently characterized by high soil disturbance and solely depend on use of synthetic fertilizers and insecticides. Adopting soil conservation techniques increases mortality and decreases reproductive output for the major insect pests of different field crops and vegetables. Well known mechanisms responsible for such effect include huge development of population density of many of natural enemies such as predators, parasitoids, enhancing plant defenses mechanism by producing secondary metabolites, and modified agricultural habitats by organic amendment. Still more research efforts should be needed for better understanding and elucidating the interactions between conservation agriculture and insect pest population dynamics.

Keywords: conservation-agriculture; no tillage; mulch; crop-rotation; organic-amendments

Introduction

Conventional or modern agricultural farming practices gained tremendous value delivering the maximum crop yield through intensive cultivation system. Incredible intensification through conventional farming achieved more social, ecological and economical concerns including health hazards of human being and environment pollution^[38]. Extensive tillage operation, burning of crop residues and use of high external inputs are considered as major part of conventional agriculture which lead to dilapidation of soil quality through loss of organic matter, soil organic carbon, destruction of soil structure, destroying the soil inhabiting fauna^[19]. Traditional agriculture, based on intensive tillage and highly mechanization, has been accused of being liable for soil erosion problems, surface and underground water pollution, and more water consumption^[17]. Moreover, it is highly concerned in land resource destruction, reduction in biodiversity, loss of wildlife, low energy efficiency and contribution to global warming problems^[16]. Ecological and Economical destructions due to devastating droughts in USA during 1930s shifted the farming concept from conventional to conservation agriculture^[24]. We moved to twenty first centuries and our major concern about environment, human, plant and other animal health forcefully shifted our cultivation strategy in a sustainable way through conservation agriculture^[27]. Conservation agriculture is a resource saving agricultural crop production system offering minimum disturbance in soil, permanent soil cover and crop rotation which in turn enhance the soil quality in terms of increasing of soil organic matter, sequestering more soil organic carbon, and diversity of soil organisms^[25, 26, 31]. Conservation agriculture contributes lot of positive impacts through a conservative way of farming on the global ecosystem and environment compared to the conventional method. Conservation agriculture systems promote the soils to have a richer biodiversity and bioactivity, better soil structure and cohesion and very high

natural physical protection against weather^[14]. Conservation agriculture production systems are now increasing interest in most countries around the globe due to its benefits in conservation of natural resources. It is now being practiced from the Arctic Circle (e.g. Finland) over the tropics (e.g. Kenya, Uganda) to about 50° latitude south (e.g. Malvinas/Falkland Island). It has been also extending from sea level to 3000 m altitude (e.g., Colombia), from extremely dry environmental conditions having 250 mm annually (e.g., Western Australia), to extremely rain fed areas with 2000 mm a year (e.g., Brazil) or 3000 mm a year (e.g., Chile)^[25]. Globally conservation agriculture (CA) is being practiced on about 125 M ha. Globally USA (26.5 M ha), Brazil (25.5 M ha), Argentina (25.5 M ha), Canada (13.5 M ha) and Australia (17.0 M ha) are considered as major countries practicing conservation agriculture. In India CA adoption is still in the initial phase. Over the past few years, adoption of zero tillage and CA has expanded to cover about 1.5 M ha^[35].

Soil tillage can enhance or decline the antagonistic pressure depending upon the pest concerned. Tillage not only the solution, integrating alternative methods like cultural, mechanical, physical, biological provide the ultimate long term solution through integrated pest management strategy. Integrated pest management is not only compatible with the conservation agriculture but work on similar principles with conservation agriculture. For example, through IPM tools population of natural enemies in the field can be augmented which can be effectively utilized as biocontrol agent against the insect pests. Similarly, conservation agriculture emphasizes on the maintenance of the biodiversity which in turn augment the population of natural enemies in the field^[30]. Crop rotation is one of the major insect management strategies in IPM which is a mandatory principle in conservation agriculture. Combining conservation agriculture

with IPM would be beneficial and more economical possess less threat to ecosystem and environment [35]. Conservation agriculture is advantageous for controlling the insect pest by enhancing the upper and below ground biodiversity by covering the ground with natural vegetation which promotes the existence of more beneficial soil fauna [36]. Covering the soil with vegetation accelerates the population density of predators and parasitoids against many insect pests [33]. Keeping these contexts in view, impacts of conservation agriculture practices on insect pest management are reviewed in the present text.

Records of insect pest problems associated with the conservation agriculture system

Cutworm

The black cutworm, *Agrotis ipsilon* (Hufnagel) was reported as the most damaging insect pest of corn seedlings under reduced tillage systems compared to conventionally tilled plots [39, 35]. In no tillage condition 15% corn seedlings were infested whereas in conventional field it was only 1% [18]. They considered that residue retention in reduced tillage provided the conducive environment for their oviposition and survivability of larval population.

Wireworm: It has been reported that Wireworm (*Conoderus* spp.) population was high in no-tillage corn field compared to the conventional tillage field. Due to minimum soil disturbance, the insects cannot be destroyed by tillage and the increased soil moisture in reduced tillage could provide the cozy environment for their oviposition and larval growth. Their infestation leads to formation of aborted seeds and weak seedlings [39].

Corn root worm: Northern corn root worm (*Diabrotica longicornis*) and western corn root worm (*Diabrotica virgifera*) are considered as major root feeding insect pest of maize cultivation in reduced tillage condition because the adult female prefer to lay on the undisturbed soil surface and oviposition rate is four times more compared to conventional system [18].

Root aphid: Root aphid (*Rhopalosiphum rufiabdominale*) has been considered as serious pest problem in rice, corn cultivation in reduced and no tillage systems compared to conventional tillage [40].

White grub: The impact of conservation tillage is highly favorable for the growth, development of white grub (*Holotrichia* spp.) compared to conventional tillage. In reduced or no tillage condition, lack of disturbance in soil fail to expose the grubs to parasites and predators leads to build up of huge population [39].

Seed corn beetle and seed corn maggot: Retention of crop residues on the soil surface affords a favorable environment for the oviposition and development of the seed corn beetle (*Agonoderus* spp.) and seed corn maggot (*Hylemya* spp.). Due to presence of that soil borne seed pest, seed germination is hindered in conservation agricultural practices [39].

Army worm: The population of Army worm (*Pseudaletia unipuncta*) was reported as higher in reduced tillage condition compared to conventionally tilled plots in rice, corn and barley cultivation [39].

Stalk borer: Stalk borer (*Papaipema nebris*) population was scanty in conventionally tilled corn fields compared to no-till field [39].

European corn borer: The population of European corn borer, *Ostrinia nubilalis* (Hubner) can be reduced at significant level by plowing operation but is impossible by adopting no-till system. Under no tillage condition retention of crop residues offer the suitable environment for their oviposition and further growth and development [39].

South western corn borer: The southwestern corn borer, *Diatraea grandiosella* (Dyar), is a major limiting factor for corn production under conservation tillage in some parts of the USA [39, 29].

Cotton boll weevil and boll worm: No tillage condition help in long term survivability of boll weevil (*Anthonomus grandis*) and boll worm (*Helicoverpa armigera*) in cotton cultivation where as conventional tillage can eradicate the hibernating population [36].

Variegated cutworm: Population density of variegated cutworm (*Peridroma saucia*) increased in cotton under conservation tillage practices in northern Alabama [35].

Application of Conservation Agriculture principles in insect pest management

Conservation agriculture basically relies on three principles which are linked together and must be considered for appropriate implementation process and planning. These are

Minimum soil disturbance: Minimum soil disturbance is highly beneficial for maintaining the soil health in good condition. Minimum disturbance optimizes the proportions of respiration of gases in the rhizospheric zone of crops, hasten the oxidation process of soil organic matter, restore the soil organic carbon, enhance the moisture retention capacity, water holding capacity of soil and inhibit the germination of weed seeds [26]. Effects of minimum tillage operation on insect pests vary depending on species and crops involved. Although initial survival of soil-dwelling pests could be higher in the absence of severe soil disturbance but their subsequent survival in reduced and no till agro ecosystems is often suppressed [10]. Possibility of survival of foliage feeding insect pests is usually lower under conservation tillage compared to traditional tillage activity. A review on 51 insect pest species from around the world revealed that decreasing damage with the decreasing tillage for 43% of the species, increasing damage with the decreasing tillage for 28% of the species and no effect for the rest 29% of the total species [5]. [2]. In no tillage condition, generalist predators, such as ground beetles, rove beetles, tiger beetle and spiders, appear to be the most common beneficiaries found to be effective against several soil dwelling insect pests. Generalist predators, including ground beetles, rove beetles, lady beetles and green lacewings, are known to attack Colorado potato beetle eggs and larvae [18, 19] and aphids on potatoes in reduced and no tilled fields [9, 6]. No till farming significantly delayed the colonization of Colorado potato beetle in tomato compared to conventionally tilled plots. As a result, less defoliation problem occurred in no-till plots and insecticide application was low to keep beetle populations below economic

thresholds level ^[21, 34]. Similarly, the percentage of maize plants infested by the European corn borer was twice as low on no-till fields compared to conventionally tilled fields ^[5]. No till farming modified the microclimatic condition in mustard crop resulted in maximum mean profile temperature in and minimum relative humidity during winter season showed very less aphid infestation ^[9].

Permanent soil cover by cover crops

Permanent soil cover by cover crops (live mulch) and straw (dead mulch) is very much essential to keep the soil protect against the harmful effects of direct exposure to rain and sun, to provide shelter to the micro and macro-organisms in the soil with a continuous supply of food and change the microclimate within the soil for better growth and development of soil organisms including plant roots ^[37, 14]. Mulching improves soil aggregation, soil biological activity and soil biodiversity, increase soil carbon sequestration; enhance moisture retention capacity, water holding capacity of soil and earthworm density in the soil ^[37]. Mulching reduces water evaporation from soil, help stabilization in soil temperatures and reduce erosion ^[28]. Effects of mulches on insect pests and disease transmission are perhaps less appreciated, but nevertheless substantial. Straw mulch effectively reduced aphid infestation and virus incidence in several crops including barley, faba bean, lupine and canola ^[34]. Populations of Colorado potato beetle larvae were significantly reduced in potato cultivation with straw mulch ^[29] and eggplant ^[20]. A peak of small (first and second instars) larval populations was observed during 1–2 weeks later on the mulched potato fields than on the non-mulched potato fields ^[19]. Similarly, a 6- to 10-cm layer mulching of wheat straw showed 2.5 to 5.0-fold decrease in potato defoliation caused by Colorado potato beetle ^[18]. Furthermore, it was reported that a consistent and significant reduction of aphid infestation and Potato virus Y (PVY) incidence on mulched plots in potato compared to non-mulch situation ^[34]. In case of onions, straw-mulched plots supported significantly very lower onion thrips populations compared with conventionally treated plots, which pushed the action threshold level in between 7 and 14 days later ^[38]. In addition to onion thrips, it was found that straw mulch suppressed the Iris yellow spot virus (IYSV) incidence compared with the untreated control ^[4]. Living mulches have similar repelling effects against the insect pests. Colorado potato beetle's population was very few in tomatoes planted into no-till plots mulched with hairy vetch (*Vicia villosa* L. Roth) and subterranean clover (*Trifolium subterraneum* L.) ^[2]. Beetles populations were significantly decreased on eggplant which inter-planted into crimson clover (*Trifolium incarnatum* L.) compared to eggplant planted into bare ground ^[3]. Living mulch repel the population of flea beetles (*Epitrix* spp.), but they appeared to be not significantly inclined by the presence of the living mulch as compared to the Colorado potato beetles. Potatoes planted into plots with hairy vetch or winter rye (*Secale cereale* L.) had lower Colorado potato beetle populations. Furthermore, aphid (*Brevicoryne brassicae*) infestations were significantly reduced in crops which incorporating living mulches ^[24, 34]. Additionally, living mulches of various clover species abridged the onion thrips populations in leek plants (*Allium ampeloprasum* L.). Reduction in insect pest populations on mulched plots driven by several mechanisms. First, mulches may spoil the capability of some insects to find their respective

host plants, or they bound to move between host plants within the field ^[10, 24, 33] and insect pests spend more time searching for suitable hosts when vegetables are hidden in a thick stand of mulch than when on bare soil and delay in find out of the suitable host make the host non synchronized with its susceptible stage with the insect pests ^[3]. Second, mulching help in augmentation of natural enemies' population and improve biological control. Mulching increased predation of Colorado potato beetle eggs and larvae by inviting so many generalist predators including ground beetles, rove beetles ^[18, 19]. The addition of barley strips into the potato fields for conservation biological control resulted in nearly a three-fold decrease in peak aphid infestation. Moreover, the numbers of winged aphids in that study were significantly lower compared to the potato monoculture. Biological control could be further enhanced by using selective biorational insecticides. For example, using novel insecticide such as Spinosad was found to be effective in suppressing the onion thrips populations by allowing the predator *Aeolothrips intermedius* Bagnall ^[24]. Actinomycetes bacteria have been reported as effective biocontrol agents against bacterial diseases of onion ^[1] and actinomycetes population flourished when organic matter is added sufficiently ^[4] which is provided by straw mulch. Thirdly, the physical or chemical properties of the mulch contribute to pathogen and insect pest suppression. Physical obstruction and alteration of the environment were suggested as mechanisms in suppression of Colorado potato beetle by straw mulch ^[18]. Interference of straw mulch in the pupation and emergence of onion thrips was investigated in the laboratory to find that their emergence was reduced by 54% compared with bare soil ^[28]. Chemical properties of mulch may play a role as well. Mulch beneath avocado trees reduced peak emergence of thrips and it was suggested that this may be due to release of secondary plant compounds ^[20]. The discovery and utilization of phytochemicals (secondary metabolites) is very promising against suppression of many insect pests. Piperamides, an extract from piper seeds was reported as very promising neurotoxic compound and inhibit cytochrome P – 450 enzymes in stripped cucumber beetles (*Acalymna vittatum* Fabricius) and lily leaf beetle (*Lilioceris lili*). Bruceines, derived from *Brucea antidysenterica* are reported as antifeedant agent against tobacco budworms, Mexican bean beetles and southern army worms. Limonin and Nomilin are two Limonoid compounds derived from citrus plant reported as very good antifeedant compound against wide range of lepidopteran and coleopteran insect pest species ^[23, 4]. Secondary metabolites such as bisamides, rocaglamides, triterpenes and lignin's reported from *Aglaia* sp. showed brilliant antagonistic activity against *Spodoptera littoralis*, *Ostrinia nubilalis*, *Helicoverpa armigera*, *Spodoptera litura*, *Chloroxylon swietenia* and *Chilo partellus* ^[28]. By inclusion these plants into the existing cropping system crop protection will take place naturally.

Diversified crop rotation

The crop rotation is very necessary to offer a diverse diet to the diversified soil microorganisms and also helpful for exploring different soil layers for nutrients that ultimately enhance the nutrient use efficiency by the crop. Furthermore, crop rotation leads to a diverse soil flora and fauna. Cropping sequence and rotations by involving legume crops helps in minimizing rates of population buildup of insect pest species, through life cycle

disruption, releasing secondary metabolites, increase the soil fertility through biological nitrogen fixation, control of off-site pollution and enhancing biodiversity [27]. Multi-layer crop rotation was found very effective as it suppresses the southern

corn rootworm *Diabrotica undecimpunctata howardi* and European corn borer *Ostrinia nubilalis* at 38% and harboring maximum predator and parasitoid populations in maize field compared to no rotation system [20].

Table 1: Effect of Conservation agriculture on insect pest management in different crops across the world

CA principles	Crop	Influence on insect	Country
1. Minimum Tillage	Wheat	Minimum tillage augment the population of predatory insects than conventional tillage	USA [14]
	Wheat and Rapeseed	Accelerate the emergence of more predators and parasitoids than ploughed plots	Sweden [23]
	Wheat and Maize	Approximate emergence of 43% insect pest species was reduced due to no tillage	USA [44]
	Maize	Oviposition rate of Northern corn rootworm beetle (<i>Diabrotica longicornis</i>) was increased four times in no tillage condition but their damage potentiality was significantly low in minimum tillage.	USA [37]
	Legumes	Zero tillage and retention of rice stubbles as a live mulch reduces the population of leaf hopper <i>Amrasca bigutulla</i> and bean fly <i>Ophiomyia phaseoli</i>	Philippines [35]
	Maize	Population of fall army worm drastically reduced in no tillage condition than conventionally plowed field	Costa Rica [21, 22]
	Cotton	Reduction of the population of <i>Lygus</i> spp. reduced tillage condition	USA [36]
	Soybean	Oviposition rate of green cloverworm <i>Plathypena scabra</i> was high in no tillage condition but subsequent larval population was lower due to presence of predators and parasitoids	USA [36]
	Soybean	Population of seed corn maggot, <i>Delia platura</i> was higher in conventional tillage than no tillage	USA [33]
	Alfalfa	Population density of Alfalfa weevil, <i>Hypera postica</i> was reduced under no tillage treatment.	USA [12]
Alfalfa	Build up of invading population of <i>Empoasca fabae</i> was reduced under no tillage condition	USA [37]	
2. Crop rotation	Maize and Soybean	Check the population build up of corn rootworm	USA [26]
	Maize, Soybean and Alfalfa	Rotation of Maize-Soybean for four years in reduced tillage system aggravate the population of Carabid beetle than 2 years of conventional system	USA [24]

Organic amendments for insect management

Soil organic matter is the most crucial component which determining the soil health status, and accelerate the growth and development of many soil dwelling beneficial organisms. Higher amount of organic matter aggravate the abundance, diversity, richness and activity of soil-dwelling beneficial organisms. Soils that are rich in organic matter provide a conducive environment for the growth of crop plants. Crop grown in organic matter rich soil less susceptible to broad range of insect pests by showing their antibiosis and antixenosis activity [8]. Growing potato on manure amended soils resulted in a significant reduction in plant infestation by Cultivation of potato plant under organic matter amended soil show less infestation to Colorado potato beetles compared to the plants grown in unamended soils [7] [17]. Organic amendment showed negative impacts on female fecundity rate [7] and developmental rate of immature stages [7] [17]. The European corn borer (*Ostrinia nubilalis*) oviposit significantly more eggs on maize plants grown in conventionally managed soil compared to maize grown in organically managed soil. Similarly, population densities of the green peach aphid (*Myzus persicae*) were higher on synthetically fertilized cabbage plants compared to organically managed soils. The organic matter content and microbial activity associated with organically managed soils supply the relative amounts of nutrients necessary for growth and development of anti-herbivore defense mechanism in plants. Plants grown on soils which are not organically amendment benefit insect pests by supplying them with an abundance of certain nutrients, and free amino acids and sugars. At the same time, the plants may lack with some precursors agent which is necessary for synthesizing defensive secondary compounds.

Organic soil amendments also increase populations of soil microorganisms [13]. Higher organic matter result in more robust populations of natural enemies, both by improving abiotic environment for their survival and by providing additional food items, in particular soil-dwelling detritivores [15].

Current and future strategies

Conventional tillage-based agriculture system has been highly criticized for using surplus number of pesticides and high cost-effective external inputs. Considering the environmental and economic point of view, significant effort has been taken for developing conservation tillage systems across the globe that emphasized to the use of natural resources instead of external inputs. To achieve the best platform based on conservation tillage focusing on the minimum disturbance of soil, covering the soil with crop residues and crop rotation should be taken into consideration for the reduction of the need for chemical fertilizers and pesticides. Incorporation of cover crops and crop rotation systems is useful which increase organic matter content, nitrogen acquisition in the soil, suppress weeds and other soil inhabiting insect pests. Vegetation covers with retention of residues harbor the existence of many predators and parasitoids against many insect pests [36]. Conservation tillage undoubtedly will be an integrated part of Integrated Pest Management (IPM) strategies in future for management of insect pest in an excellence way.

Conclusion

Improvement of the sustainability of soil, water, and soil fertility management through soil conservation practices that have the potentiality for insect pest management further should thrust for

adoption globally. Increased complexity of agricultural ecosystems supported by less disturbed soils creates an environment that is less conducive to outbreaks of herbivorous insect pests. However, the existing body of evidence is heavily weighted towards mulches and organic soil amendments, conservation tillage, cover crops. More research work is needed to gain a better understanding of other aspects of soil management on the suppression of insect pests of different field crops through conservation agriculture which are likely to further increase an importance with the gradual shift of mainstream agricultural practitioners towards more sustainable soil stewardship.

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