Review articles & Short notes

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Minimise disturbance, maximise control

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Abstract

Biological control is the use of parasitoids, predators, and pathogens in keeping the density of other organisms at a lower average than it would otherwise be. Worldwide, pest suppression from insect natural enemies, such as predators and parasitoid wasps is valued at over US$400 billion annually. Agricultural intensification related disturbances (pesticide use, tillage, fertilizer use, crop harvest, low-diversity agriculture systems & climate change) limit our ability to produce sustainable crop production. These disturbances are caused by crop management practices and they can make agricultural fields more vulnerable to insect outbreaks since natural enemies are more susceptible to disturbances. Considering disturbances that influence natural enemies, conservation practices are discussed that can mitigate or counteract disturbance. The natural enemy's population can be improved mostly by conservation biological control methods like providing alternative food resources, overwintering sites, intercropping methods, maintaining non-crop habitat and reducing the impact of pesticides by screening & selecting the most compatible one to natural enemies (e.g. Spinosad).

Keywords: Agricultural intensification, farming, natural enemies, organic agriculture.

Natural enemies –Farmer's friends

Important natural enemies of insects and mite pests include predators, parasites and pathogens. The types of natural enemies are

Predators: A predator is an organism that attacks, kills and feeds on several other individuals (its prey) in its lifetime. Immature and/or adult stages can be predatory. Some predators feed on a wide range of species (*generalists*), while others are more specialized in their choice of prey by feeding on only one or a few species (*specialists*). Most of the predator population belongs to the orders like Coleoptera, Hemiptera etc.

Parasitoids: A parasitoid is an insect parasite of an arthropod which is parasitic only in the immature stage and adults are free-living. Around 8.5% of insect species documented till date (*i.e.*, approximately 85,000 species) are parasitoids with Hymenoptera and Diptera being the most common. The larvae can feed both within and outside their host's body species are classified as either solitary with only one parasitoid developing per host or gregarious with many larvae (often hundreds) growing per host.

Pathogens: Pathogens are disease causing organisms (fungi, bacteria, viruses, nematode worms and microsporidia). They can be important to check the growth of pest populations in agricultural systems.

Disturbances in agro-ecosystems and their influence on biocontrol

In modern, high-input farming, several common features limit the potential for natural control to prevent pest outbreaks such as pesticide use, tillage, fertilizer use, and crop harvest. These activities tend to decrease the abundance of natural enemies and the control that they can provide.

Pesticide usage

Pesticides are routinely used as the tool and the first choice to control crop pests. Pesticides can reduce the effectiveness of the natural enemies of arthropods by causing mortality and by influencing their movement, foraging and over reproductive rate (Jepson *et al.*, 1989).

i. **Insecticide use**: Nowadays farmers are going for management-intensive systems and tend to use insecticides preventatively which can limit natural-enemy populations, often resulting in pest resurgence or outbreaks of secondary pest species that can decrease crop productivity. e.g. Synthetic pyrethroids cause resurgence of white fly in cotton.

ii. **Herbicides use**: Herbicides limit the abundance of non-crop plant species in agro-ecosystems and can have direct and indirect effects on natural-enemy populations within crop fields. e.g. *S*-metolachlor was highly toxic having 80–90% mortality on *Phytoseiulus persimilis.*

iii. **Fungicide usage**: Fungicides can disrupt natural control of some insect and mite pest species as many are toxic to entomopathogenic fungi, e.g. Smith *et al.,* 2000 reported an 80% reduced arbuscular mycorrhizal root colonization due to a benomyl fungicide application.

Tillage

Tillage is used as a weed-management tactic and to prepare seedbeds but can have strong influences on soil-dwelling arthropod populations including natural enemies. Tillage for weed control also is physically disruptive to species that enter spaces within the soil for shelter or to pass some stage in their development. Tilled fields tend to have fewer predators than non-tilled fields, whereas herbivorous insects tend to occur equally often in the two types of fields, suggesting that crops in tilled fields may be more vulnerable to pest damage because of an absence of top-down control.

E.g. Carabids often enter earthworm tunnels to seek damper, cooler soil but such tunnels are destroyed by cultivation. Plowing of soil in Swedish crops reduced the emergence of parasitoids of pollen beetles, *Meligethes sp*., by 50 to 100% in spring and winter crops (Nilsson,1985).In Canada, tillage killed 95% of *Tetrastichus julisa* key parasitoid of cereal leaf beetles and it's absence led to the outbreak (Ellis *et al.*, 1988).

Fertilizer usage

Fertilizer use can also disrupt services provided by beneficial organisms. The study showed that even moderate application of phosphorus fertilizer can reduce arbuscular mycorrhizal colonization and spore numbers by 50% (Martensson and Carlgren,1994). This finding indicates that fertilizers that are meant to increase plant growth may actually diminish the natural ability of soils to provide nutrients to plants.

Crop Harvest

Crop harvesting can also be considered as a disturbance, particularly from the standpoint of natural-enemy populations the absence of which can allow pest numbers to grow. e.g. In alfalfa the parasitoid population of aphids *i.e.*, *Hyperapostica* and *Lygus spp.* got killed (Van Den Bosch *et al.*, 1967).

Effect of Elevated Temperature: In the context of global warming scenario induced by climate change, all species will be under strong selection pressures and natural enemies are no exception (Nayak *et al.*, 2020).

i. **Effect on host searching ability:** Parasitoids can sustain a broad thermal range, although exposure to temperature extremes even for short periods is likely to influence parasitoid survival and host searching ability. Studies from 1993 to 1996 correlating climate data with egg parasitism suggest that rate of egg parasitism by *Trichogramma* spp. on European corn borer was drastically reduced to zero owing to extremely dry and hot weather experienced in May 1993 in Slovakia (Cagan *et al.*, 1998). Similar study on tachinid flies in relation to increased temperature suggests reduced range of parasitism up to 51%. Host location falls off sharply at temperatures above 35 ^{0}C of the egg parasitoid, *Trichogramma carverae* Oatman and Pinto (Thomson *et al.*, 2001). In case of predators, it could be different. For example, it has been predicted that coccinellids reduce aphid population more strongly in hot summers than in moderate summers.

ii. **Effect on host tracking by natural enemies:** It is predicted that a 1^{o}C rise in temperature would enable species to spread 200 km northwards or 140 m upwards in altitude. Herbivore pests having greater mobility are likely to track the expansions. For example, rise in temperature will allow the pink bollworm, *Pectinophora gossypiella* (Saunders) to expand its range to non-traditional cotton growing areas that are presently non habitable (Guiterrez *et al.*, 2006 or 2008). Mobile species such as diamond back moth, *Plutella xylostella* L. and European corn borer, *Ostrinia nubilalis* (Hubner) will track the new areas faster than less mobile species. The probability of hosts escaping their specialist parasitoids will be highest as they may struggle to track the spatial shift of their host. These changes in the distribution of crops and expansion of herbivores range may lead to escape of these pests from natural enemies which may ultimately affect the pest control.

iii. **Phenological asynchrony between natural enemy and herbivore host:** Mismatched phenological asynchrony between a parasitoid and its host has been reported in several of cases. Graben weger *et al.,* 2007 reported lower level of parasitism in the first generation of horse chestnut leaf miner, *Camerariao chridella* Deschka & Dimic, which might be due to emergence of hibernating parasitoids of leaf miners at a time when hosts are not available.

Methods to conserve

Ecological Engineering (EE): It is a new paradigm to enhance the natural enemies of pests in an agro-ecosystem and is being considered an important strategy for promoting Bio-intensive Integrated Pest Management (BIPM). This approach relies on use of cultural techniques to bring about habitat manipulation and enhance biological control. Ecological engineering emerged as a paradigm for considering pest management approaches that are based on cultural practices and informed by ecological knowledge rather than on high technology approaches such as synthetic pesticides and genetically engineered crops. (Gurr *et al.,* 2004). The primary objective of ecological engineering is to make the environment of the agro-ecosystem suitable for better survival of natural enemies of pests. Habitat manipulation aims to provide natural enemies of pests with nectar, pollen, physical refuge, alternate prey, alternate hosts, and living sites. This can be through the plantation of appropriate companion plants like floral trap crops and repellent crops, through which the population of pollinators, predators, and parasitoids can be enhanced to manage the herbivorous insect pests.

Crop-residue destruction should be minimized in Indian sugarcane, several parasitoids like *Epiricania melanoleuca*, *Ooencyrtus papilionis*, *Parachrysocharis javensis* of the sugarcane leafhopper *Pyrilla perpusilla* are eliminated when crop residues are burned. Studies show that if crop residues are left unburned and spread back on the field after burning, parasitoids can be conserved at levels able to control the pest (Joshi and Sharma1989, Mohyuddin 1991).

Plant-flush pest synchronization: A synchronized flush of new growth may follow after some woody plant crops are pruned. Young foliage is often higher-quality food for insects, especially sucking species. A surge in pest population growth rate may follow that exceeds the ability of parasitoids to numerically respond quickly. High pest densities may result from this imbalance. To prevent these events, growers can use alternate-row pruning (which staggers the growth of succulent new foliage, which is attractive as oviposition sites for pests such as whiteflies). This approach prolongs the induction of increased pest populations, allowing more time for parasitoids to respond. Biological control of whiteflies in lemon orchards was improved in coastal California by the use of alternate-row pruning (Rose and De Bach, 1992).

Direct seeding and no-till While not intended as a tool to better conserve natural enemies, no-till agriculture creates a more favorable environment by enhancing soil moisture, reducing soil surface temperature, and preserving soil structure. (Jackson and Pitre, 2004).

Strip harvesting: Strip harvesting rather than cutting whole fields at the same time can help preserve natural enemies in forage crops by preserving both the physical environment and a host or prey supply for natural enemies. Strip harvest of alfalfa, for example, help certain populations of parasitoids of aphids, alfalfa weevil *Hypera postica* and *Lygus spp.* (Vanden Bosch *et al.*, 1967). Nentwig (1988) found that when German hay meadows were strip harvested, predaceous and parasitic arthropods, especially spiders, became more abundant and herbivores decreased.

Semiochemicals: These are the substance released by an organism that affects the behaviour of other organisms. When terminal bud gets infested by maize aphids, *Rophalosiphum maydis* (Fitch), the E-β farnesene (alarm pheromone) is released by herbivores and HIPV'S by plants helps in attracting coccinellids, other predators, and parasitoids for aphid control (Rehman *and* Powel, 2010).

Applying semio-chemicals: Lures may also be used to attract released natural enemies to help them establish themselves. Applying attractants in combination with food sprays may promote the oviposition of released chrysopid predators into the target crop. Hexane extract of corn borer larvae was applied on corn plants to enhance the performance of larval parasitoid *Bracon brevicornis* adults against the corn borers *Ostrinia nubilalis* and *Sesamia cretica*.

Selective use of pesticides: There is an urgent need to develop truly selective pesticides for the conservation of natural enemies by using active ingredients with the least non-target toxicity. Undesired side effects of pesticides on natural enemies could be further reduced by adopting the timing, place and mode of application. Some examples for selective use of pesticides are spinosad, IGR and azadirachtin.

Genetic improvement through selection: Natural selection created populations of pesticide-resistant natural enemies in routinely sprayed crops such as apple. Resistant populations can also be developed artificially in the laboratory. Pesticide-resistant populations of many predatory mites have been discovered (or selected): *Metaseiulus occidentalis*, *Aphytis holoxanthus* DeBach (Havron *et al.*, 1991) and *Aphytis melinus* DeBach (Havron *et al.*, 1991) are scale parasitoids (Rosenheim and Hoy 1986). Endograma is an endosulfan-resistant strain of *Trichogramma chilonis* produced by NBAIR in Bangalore.

Conclusion

Conservation techniques can help to minimise or counter balance perturbations that reduce natural enemies' ability to offer top-down suppression. Non-crop habitat that can assist preserve natural enemies and the natural control they offer may be insufficient in some agro-ecosystems to lower insect populations to economic harm thresholds. So, providing the modified habitat that supports natural enemies sufficiently enough to achieve biological control. The more farmers who can rely on conservation biocontrol the more it will be able to assist shift agriculture toward sustainable intensification by adopting strategies that utilize natural capital more intensively to avoid negative environmental consequences of farming. Some conversation methods provide additional benefits like cover cropping is a conservation method that is extensively supported for its ability to reduce erosion and increase soil quality, nitrogen cycling, and weed control, among other ecosystem services. Cover crops can provide predator habitat and assist raise predator numbers early in the growing season resulting in better pest management. Organic farming reduces neighborhood disruptions and provides better pest management. To conclude this study, we argue to minimize disturbances and maximize diversity of the agro-ecosystem by practicing the suitable conservation methods which will maximize the natural control.

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