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Insights into Biointensive Management of Aphids: A Broad Perspective

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ABSTRACT: Biointensive integrated pest management is a more dynamic and ecologically informed approach to IPM, it's a recent concept that aims to alleviate pesticide pressure and brings up new options for bio-control and the use of bio-rational agents, which are less harmful to the environment and affect only targeted insects. To achieve effective, efficient, and reliable pest suppression, the term "bio-intensive integrated pest management" (BIPM) is employed, focusing a strong focus on the preservation and strengthening of natural enemies and the application of all appropriate interventions. It encompasses all traditional non-chemical pest control techniques, combined with predators, parasitoids, botanical pesticides and pesticides generated from microbes. For sustainable management of aphids in crop fields, BIPM could play a significant role, the use of entomopathogenic fungi, biorational and botanicals efficiently manage the aphids when their population is at its peak. Certain coccinellids and some parasitoids are also keys to managing aphids efficiently. In comparison to adequate chemical control, a proper blend of cultural, physical, and biological control techniques along with biopesticides might effectively manage the aphid population in field conditions. This review article offers an appropriate management practice plan and lets the reader know about major aphid species found in India and how Biointensive integrated pest management tactics could be employed to manage the aphid population in the field.

Keywords: Biointensive Management, Aphids, Agricultural crops, Horticultural crops, Integrated pest Management, Biological control.

INTRODUCTION

Aphids constitute an important category of agricultural pests that reduce crop output and inflict substantial harm to plants both directly and indirectly as disease vectors (Sarwankumar, 2019). Aphididaeis a family with over 4700 different species worldwide (Remaudière and Remaudière 1997). There are roughly 450 species that have been identified to infest crop plants, but only about 100 of them have been able to effectively adapt to the agricultural environment. While being a tiny group of 450 species, they have effectively exploited the agricultural environment to the position that they are economically significant (Blackman and Eastop 2000). The subfamily Aphidinae comprises the majority of the aphids that feed on herbaceous plants (Blackman and Eastop 2006). Aphids are widespread practically throughout, but they are most frequent in temperate regions. Unlike most of the taxa, the diversity of aphid species is substantially lower in the tropics than in the temperate zones (Zyla *et al.,* 2017).

Aphids have several biological features, including thelytokous parthenogenetic viviparity, short generation period, telescopic generations, and polymorphism. Because of these reproductive features, aphids can swiftly colonize ephemeral resources and establish plants, making them great crop pests. Many aphid species have complex life cycles with sexual and asexual generation alternation as well as host plant alternation (Minks and Harrewijn 1988). These are specialized phloem sap feeders,that cause considerable output losses in a variety of crops. Despite the fact, some crops are more severely harmed than others, aphids pose a significant threat to global food production. At least one type of aphid attacks every crop on the globe (Peters *el al.*, 1991). Their capacity to quickly exploit transitory environments makes them major pests, and this ability emanates from their strong reproductive capabilities, dispersion capacities, and adaptation to local survival (Dedryver *el al.*, 2010).

Aphid harmscrops and reduces yields in several ways. They may harm plants by withdrawing enough sap to induce wilting and death, as well as by building high population densities, which remove plant nutrients. If left on plants, aphid honeydew can accumulate to the extent that it serves as a growth substrate for sooty moulds, which hinder photosynthesis and spread other fungi-related infections. Some aphids' salivary secretions are phytotoxic, causing stunting, leaf distortion, and gall development, which is especially problematic for horticulture. Even if they are otherwise asymptomatic, Aphid feeding impacts may alter plant hormone equilibrium, modifying the host's metabolism to their favor and effectively taking over the physiological processes of the plant, (Bhatia *et al.*, 2011). The spread of plant viruses is the most critical issue caused by aphids.

Aphids gain from the viral transmission, because virus-infected plants frequently exhibit an aphid-attractive yellowing and have more free amino acids. Stylet-borne viruses are epidermis pathogens that are not aphid-specific. They are promptly acquired and transferred when the plant's epidermis is probed rostrally. When the aphid moults, these non-persistent viruses lose their infectiousness. Contrastingly, circulating viruses require an incubation period before they spread successfully since they are housed in the aphid's stomach. They are persistent viruses, and an infected aphid serves as a vector for the rest of its life. Circulating viruses have rather particular virus-aphid-plant relationships, and each given virus is only spread by one or a small number of aphid species (Dixon, 1998).Aphid's nutrition plays an important role in biological behavior and wing development, when their hosts produce a significant amount of nutrients, apterae are developed selectively. When an aphid population reaches a threshold that causes crowding and affects the nutrition levels of its host, it often shifts to the generation of alatae. This enables dissemination to better food environments and improves the clone's genetic survival, to the seasonally inadequate supply of nitrogen-based nutrients, especially amino acids (Minks and Harrewijn 1988). The specific feature of aphid feeding is Pectinase-containing saliva that is used to lubricate the stylets, which also helps to break up the bonds between plant cells and create a sheath that is left behind once the stylets are detached. Aphid guts have developed into specialized cell clusters called mycetomes, which contain symbiotic bacteria that are identical to rickettsia and assist in the manufacture of nutrition (Remaudière and Remaudière 1997).

Despite of a polyphagous pest, aphids thwart the parasites and predators by employing chemical and auditory communication. Aphids release tiny drops of the alarm pheromone trans-farnesene from their siphuncular pores when they are threatened. As a result, nearby aphids hurriedly descend to the ground to fled. Oviparousaphids attract males by emitting sexual pheromones from specialized pores on their hind tibiae (Blackman and Eastop 2006). Aphids have a complicated feeding pattern and coping strategies over natural enemies. Certain tactics and methods (including biotic and abiotic elements), could be used to manage the aphid population in a crop field. And bio-intensive integrated pest management incorporates both biotic and abiotic elements to control aphid population. Major aphid species affecting field and horticultural crops in India are enlisted in Table 1.

Table 1: List of major aphid species feeding on different field and horticultural crops.

Host category	Aphid Species name	Crop general name
Field crops	*Aphis gossypii,*	Cotton, Castor,
	Aphis craccivora	Pigeon pea, cowpea, beans, Groundnut.
	Aphis nerii	Maize, wheat
	Myzus persicae	Potato, cotton, Tobacco
	Lyphapis erysimi	Rapeseed and mustard
	Melanaphis sacchari	Sugarcane
	Rhopalosiphum maidis	Sorghum, Maize, Wheat
	Ceratovacuna lanigera	Sugarcane
	Sitobion avenae	Wheat, millets.
Horticultural crops	*Aphis gossypii*	Okra, Brinjal, Cucumber, China rose, Chrysanthes, Beetlevine.
	Myzus persicae	Radish, Cabbage, Tomato, spinach, Brinjal, Chilli.
	Aphis fabae	Potato, Tomato, Sugarbeet, Merigold, Sunflower, Red orachm, Chamomile, Chrysanths, Opium poppy,
	Aphis nerii	Olender, Periwinkle, Lemon
	Aphis craccivora	Tulsi
	Toxoptera aurantia	Citrus
	Pentalonia nigronervosa	Banana, Cardamom.
	Aphis punicae	Pomegranate.
	Macrosiphum rosaformis	Rose
	Bravicoryne brassicae	Cabbage.

Biointensive Integrated Pest Management of Aphids.

Pre-requisites of Biointensive Integrated pest management for aphids.

Baseline data collection through survey and surveillance. Baseline data or information is critical for understanding the true image or state of farmers' perceptions of biologically intensive pest management. The baseline survey is used to determine farmers' pest perceptions, pest control strategies, and decision-making process, as well as basic socioeconomic data and other information.

Identification of Major aphid species Correctly and Accurately. The diagnostic process entails inspecting the entire plant as well as its parts, carefully interpreting the observations, and seeking to determine why injuries or damage occurred. Before making a management decision, evaluate the sorts of species present in the field, their style of feeding and their damaging patterns. Correct identification of the species of aphid is essential to make strategies against specific aphids (selection of parasitoid and fungal biopesticides). An incorrect diagnosis may result in the inappropriate selection of natural enemies and the waste of money in management efforts.

Monitoring, Scouting and Forecasting. Estimating insect pest population sizes is a fundamental activity in ecology and the foundation of integrated pest management (Pedigo, 2001). Monitoring and forecasting in the context of aphids as crop pests are ultimately aimed at optimizing the nature, location, and timing of control interventions. Various methods of monitoring aphid species like, *in situ* counts on plants, Destructive counts on plants, Sweeping, Aerial sampling, Sticky traps, Sex pheromones, Suction traps and Filter traps, could be employed for sampling and monitoring (Taylor and Palmer (1972). There are two types of forecasting tools. First, big data sets are being employed to create phenomenological models using a purely statistical technique. Second, process-based simulation models have been developed using gathered scientific knowledge on the biology of the target species (Kindlmann *et al.*, 2017). The better the sampling and monitoring will be, the better will be the management practices.

Determination of Threshold level. The foundation of integrated pest management as presented by Flint and van den Bosch (1981) is based on sampling, economic thresholds, and natural mortality in agroecosystems. The economic threshold level of aphid species varies species to species and on the bases of the crop on which it feeds, e.g., ETL for mustard aphid in the mustard field is 22 aphids per 10 cm length of the twig on the top portion of the central shoot or infestation of 30 percent plants (Bhanu *et al.*, 2019). ETL for the crop on which the aphid is feeding should be determined accurately using old records of that species or through regular monitoring of the pest in the field, so that management measures can be applied at the appropriate time to prevent the aphid population from reaching EIL. In general, the ETL is the first 75 of the EIL (Pedigo and Higley 1992).

Tactics of Bio-intensive Integrated Pest Management for aphids. Aphid control tactics are divided into two categories: therapeutic and preventive. To manage pest population growth, these strategies include cultural, mechanical, physical, chemotherapeutic, regulatory, biological, plant resistance, and genetic approaches, to prevent the pest population from reaching ETL.

Cultural measures. The common thread of cultural control is to decrease of aphid damage through crop management of the physical or biological environment, either at the establishment or during growth. However, numerous strategies are at work. These range from physically shielding crops against aphids to increasing aphid mortality by providing aphid predators with out-of-season refuges. Some are used in conjunction with biopesticides, and others are considered more benign alternatives (Harrewijn and Minks 1989) or they may involve multitrophic-level interactions between species that are very difficult to predict (Tscharntke and Hawkins 2002; Brewer and Elliott 2004). Some mostly adopted cultural control measures for aphid management are as follows,

Sowing and planting date. Changes in the regular date of sowing could assist the grower in controlling the time of crop sensitivity in connection to aphid reproduction, growth rate, and dispersal of aphids and their natural enemies. Sowing date influences plant growth at the time of aphid colonization, which may affect aphid migration across plants and arriving alatae perception of the crop. The direct effect of weather on plant growth, limits the extent to which aphid damage may be regulated in this manner, but it has proved a successful strategy in some situations. For instance, in mustard early sown mustard showed less mustard aphid (*liphapis erysimi*) population as compared to late sown (Saha and Baral 1999). Similarly, in tobacco the plant sown in late March showed less mustard aphid (*Myzus persicae nicotianae*) population as compared to plants that were sown in mid-April (McPherson *et al.,* 1993). However, delayed sowing of barley in northern England showed low aphid density (McGrath and Bale, 1990). While, no effect of changing the sowing dates was found on cotton against *Aphis gossypii* in Texas, USA (Parajulee *et al.,* 1999). Sowing date effects may lead to differences in the incidence of plant diseases such as Barley yellow dwarf virus (BYDV) (Snidaro and Delogu 1990).

Trap cropping. Trap crops can be used to either restrict aphids from accessing the target crop or to centralize them in an area where chemical or other management methods, such as plant death, are more effective (Hokkanen, 1991). Trap crop does not serve as a continuous pest sink; nevertheless, it may slow target crop colonization or, more crucially, serve as a sink for aphid-borne diseases (Jones, 1993; Thieme *et al.*, 1998; Fereres, 2000). Trap crops can also act as a sink for aphidophagous species (Cameron *et al.,* 1984).

Irrigation and fertilizer management. Aphid growth and reproduction rates are strongly influenced by the quality of sap obtained from their host plants. This varies depending on the stage of plant development, soil fertility, and water availability. High soil nitrogen concentrations are well known to cause host plants to be more heavily attacked by aphids. High amino acid concentrations in plant phloem sap have been linked to improved aphid performance (Wratten, 1974; Jansson and Smilowitz 1986; Weibull, 1987). For the management of *Aphis gossypii* on cotton crop a combination of managed nitrogen and water deficits was used, making conditions less favourable for aphids (Godfrey *et al.*, 2000). However sometimes using high nitrogen may not enhance the aphid densities in case of corn leaf aphid (*Rhopalosiphum maidis*) population was less in most fertilized conditions (Atiyeh *et al.*, 1996).

Intercropping, living Mulches and cover crops. Intercropping is the cultivation of multiple crops in a field that is spatially integrated in such a way that the environment of the plants of each crop differs from that of a monoculture. The combination of cues available to aphids arriving at, and moving within the field when aphid-susceptible crops are mixed with non-hosts is a key aspect of this environment. It has been recommended that non-host plants may interfere with the ability of specialist herbivores like aphids to find hosts (Root, 1973). Costello and Altieri (1994) found an increased rate of broccoli infestation by *Brevicoryne brassicae* (cabbage aphid) in clean cultivated plots (55%) compared with plots where strawberry clover (*Trifolium fragiferum*) was used as a living mulch (7.5%). A complex set of tritrophic interactions operates whereby a predator may not only be affected directly by variation in diversity but also indirectly by the effects of diversity on its prey (Smith, 1969). If an aphid uses chemosensory receptors to locate its host, volatiles emitted by non-host species may also have an impact on the aphid's capacity to do so.

Biological control. Biological pest control strategies fall into three main categories i.e., Classical, Augmentation and conservation. Aphid colonies are preyed upon by several predators, parasitoids, and entomopathogens. Aphids are devoured by predatory midges, syrphids, coccinellid beetle adults, larvae, and lacewing larvae (Volkl *et al.*, 2007). The most prevalent aphid pathogens are entomopathogenic fungi, primarily the Deuteromycotina and Zygomycotina. (Hajek and St-Leger 1994). The biological management of aphids to lessen crop damage is a distinct subject from how natural enemies affect the aphid population year to year.

Parasitoids for aphid management. In biological control and integrated pest management (IPM) programs, aphid parasitoids (Hymenoptera: Braconidae and Aphelinidae) have been utilized far more frequently than other natural enemies of aphids. Aphid parasitoids from the Cecidomyiidae (Diptera) are only known in the genus *Endaphis* where six species have been described (Muratori *et al.,* 2009). Parasitoids produce detrimental effects on different life stages and are classified on the stage on which they feed *i.e*., egg, larval, pupal, and adult parasitoids. Various species of parasitoids parasitize on various insect pests are described in Table 2.

Table 2: Species of parasitoids parasitizing on different aphid species.

Parasitoid species	Family	Targeted aphid species	Infesting crop	References
Aphelinus abdominalis (Dalman)	Aphelinidae	*Aulacorthum solani* *Macrosiphum euphorbiae* *Macrosiphum rosae* *Myzus persicae* *Rhodobium porosum* .	Tomato, Sweet pepper, Eggplant, French bean, Gerbera, Rose, Chrysanthemum, Strawberry	Blümel and Hausdorf (1996)
Aphidius colemani (Viereck)	Aphidiidae	*Aphis gossypii* *Aphis craccivora* *Aphis ruborum* *Myzus persicae*	Sweet pepper, Cucumber, Melon, Eggplant, Rose, Chrysanthemum, Strawberry	Bennison and Corless (1993); Mulder *et al.* (1999)
Aphidius ervi (Haliday)	Aphidiidae	*Macrosiphum euphorbiae* *Macrosiphum rosae* *Aulacorthum solani* *Myzus persicae* *Rhodobium porosum*	Sweet pepper, Cucumber, Eggplant, Gerbera, Rose, Chrysanthemum, Strawbery, French bean	Wei *et al*. (2003)
Aphidius gifuensis (Ashmead)	Aphidiidae	*Myzus persicae*	Tobacco	Boivin *et al.* (2011)
Aphidius matricariae (Haliday)	Aphidiidae	*Myzus persicae* *Aphis craccivora* *Aphis fabae* *Aphis gossipii* *Aphis nasturii* *Aphis ruborum*	Strawberry, Sweet pepper, Tobacco.	Boivin *et al.* (2011)
Ephedrus cerasicola Stary	Aphidiidae	*Aulacorthum solani* *Myzus persicae*	Strawberry, Sweet pepper.	Boivin *et al.* (2011)
Lysiphlebus testaceipes (Cresson)	Aphidiidae	*Aphis gossypii*	Melon, Cucumber	Boivin *et al.* (2011)
Lysiphlebus fabarum (Marshall)	Aphidiidae	*Aphis gossypii*	Melon, Cucumber	Boivin *et al.* (2011)
Praonvolucre (Haliday)	Braconidae	*Acyrtosiphum malvae,* *Aphis craccivora,* *Aphis fabae,* *Aphis gossypii,* *Aphis nasturii,* *Macrosiphum euphorbiae*	Strawberry, Sweet pepper, Cowpea, Urdbean, Cotton, Frenchbean, Rose, Potato.	Boivin *et al.* (2011)

Predators for aphid management. The aphid serves as a model for ecological interactions at the upper trophic level, including predation. The predatory guild that is connected to aphid colonies mostly consists of spiders, coccinellids, lacewings, anthocorids, nabids, predatory midges, syrphid flies, carabids, staphylinids, and ants (Sunderland, 1988). Ladybirds are among the most well-researched aphid predators because of their high visibility and value to many crops. The same kind of prey is consumed by both larvae and adults, who inhabit the same habitats (Majerus, 1994; Hodek and Honek 1996; Dixon, 2000). Most aphidophagous coccinellids belong to the subfamilies Coccinellinae and Scymninae. Different species of predators, preys on aphid species are enlisted in Table 3.

Table 3: List of major predators preys on aphid species.

Predator species	Family	Target aphid species	Infesting crop	References
Coleoptera (ladybirds) *Coccinella septempunctata* *Coccinella undecimpunctata* *Synonycha grandis* *Hippodamia convergens*	Coccinelidae Coccinelidae Coccinelidae Coccinelidae	*Aphis gossypii* *Lipaphis erysimi* *Myzus persicae* *Aphis fabae* *Ceratovacuna lanigera* *Diuraphis noxia*	Cotton, Okra. Rapeseed and mustard. Sweet pepper. Soybean. Sugarcane. Wheat.	Hämäläinen (1980); El Habi *et al.* (1999); Zaki *et al.* (1999) Deng *et al.* (1987)
Neuroptera (lacewings) *Chrysoperla carnea* *Chrysoperla rufilabris*	Chrysopidae Chrysopidae	*Myzus persicae,* *Macrosiphum euphorbiae* *Aphis fabae* *Brevicoryne brassicae* *Aphis gossypii* *Diuraphis noxia*	Potato. Sugarbeet. Brassicas. Cotton, Okra, Melon. Wheat.	Scopes (1969) Hassan (1978) Ehler *et al.* (1997)
Diptera *Aphidoletes aphidimyza* *Pseudodorus clavatus*	Cecidomyiidae Syrphidae	*Myzus persicae* *Aphis gossypii* *Aphis spiraecola*	Brassicas, sweet peper. Cotton. Citrus.	Messelink *et al.* (2011).

Entomopathogens for aphid management. The most frequent pathogen attacking aphids are entomopathogenic fungi, which are potentially promising biological control agents (Evans, 2003). The majority of species, including those which victimize aphids, belong to the fungi Ascomycota (order Hypocreales; examples include *Lecanicillium longisporum*, *Beauveria bassiana*, *Metarhizium anisopliae*, and *Paecilomyces fumosoroseus* and Zygomycota (order Entomophthorales; examples include *Pandora neoaphidis, Zoophthora*). Entomopathogenic fungi have evolved to make use of the resources offered by their insect hosts to kill them. They do this by immediately penetrating the cuticle of their host without the need for ingestion (Inglis *et. al.,* 2001). Several aphid species present on field crops are susceptible to virulent isolates of the fungus *Lecanicillium* spp., *B. bassiana, M. anisopliae*, and *P. fumosoroseus* (e.g., Feng and Johnson 1990; Feng *et al.,* 1990; Miranpuri and Khachatourians 1993).

Mechanical and physical measures. The use of sticky traps is a very easy approach of detecting early pest infestations and getting relative insect numbers (Parajullie *et al.,* 1999). Aphids are attracted to yellow lights, so the use of yellow sticky traps is the best mechanical measure to control aphids, for that, yellow sticky traps @10 per hectare should be installed in the field to monitor and manage the aphid population in the crop field.

Host Plant Resistance for aphid management. HPR involves modifying some anatomical, morphological, physiological, or chemical attributes of the plant. There are three mechanisms of HPR *i.e.,* antixenosis, antibiosis and tolerance.

Antixenosis includes the use of colour, palatability, waxiness, local necrosis and mechanical hardness such as trichomes of the plant parts. Colour can alter aphid migration preferences. *Brevicoryne brassicae* alatae (cabbage aphid) settle poorly on red cabbage cultivars (Radcliffe and Chapman 1965). Sugar ester levels and alpha and beta monols on the leaf surface can cause antixenosis to *M. persicae* in tobacco (Johnson *et al.,* 2002). Difficulties reaching the phloem are a more common source of mechanical antixenotic resistance. Dreyer and Campbell studied the role of pectin in the cellular middle lamella in preventing aphid entry to the phloem (1987). A higher density of trichomes on wheat leaves deters *Sipha flava* (yellow sugarcane aphid) also deters *M. persicae* on crosses of tomato with wild potato (Simmons *et al.,* 2005).

Antibiosis includes the internal plant factors which are unfavourable for the aphid species. It includes secretions from glandular trichomes, toxins, nutritional factors, and some extrinsic factors. Any *Macrosiphum euphorbiae* (potato aphid) on the stems multiply faster than on varieties without glandular trichomes (Ashouri *et al.,* 2001). The wild tomatoes *Lycopersicon hirsutum f. glabratum* and *Lycopersicon peruvianum* have a dense pubescence with both types of trichomes (Kok-Yokomi, 1978). Cotton cultivars with varying levels of the polyphenol gossypol were developed, *Aphis gossypii* showed shorter longevity and poorer fertility on a high gossypol cultivar compared to two with lower levels (Du Li *et al.,* 2004). Extrinsic factors such as the availability of natural enemies in the external environment also affect the development of the aphid population on the plants.

Use of Biorational insecticides and ecologically safer insecticides. Biorational or "reduced risk" insecticides are synthetic or natural compounds that effectively control insect pests, but have low toxicity to non-target organisms (such as humans, animals and natural enemies) and the environment (Hara, 2000). Agrochemical businesses have created new forms of pesticides *i.e*., biorational pesticides. Despite being mostly synthetic, they are more selective than conventional pesticides, making them safer, and they work well in Biointensive integrated pest management (BIPM) programs (Casida and Quistad 1998). It includes Neonicotinoids, insect growth regulators, insecticides derived from soil microorganisms and other organic and bioinsecticides.

Neonicotinoids safer for aphid management. Neonicotinoids are one of the most effective groups of biorational insecticides, particularly for suppressing sucking insects like aphids, whiteflies and leafhoppers. The nicotinic acetylcholine receptor (nAChR) of the peripheral and central nervous systems is the target (Bai *et. al.,* 1991). Sometimes they have a mild effect on natural enemies and pollinators. Several formulations of this group have proved to be more effective than carbamates, Organophosphates and other chemicals, for the management of aphids in field conditions. Some examples are Imidacloprid, acetamiprid, and thiamethoxam, they were found more effective when compared with acephate and dimethoate (Ghosal *et al.,* 2013).

Use of insect growth regulators. IGRs are grouped into categories like chitin synthesis inhibitors (CHIs), ecdysone agonists and JH mimics. Since molting and juvenile hormones regulate a variety of physiological and biochemical processes in insects, new insecticides that specifically target ecdysteroid and juvenile hormone (JH) receptor sites have been produced. (Dhadialla *et al.*, 1998). They target hormones required for the normal growth and development of an insect, inhibit the necessary process like moulting, and cause a barrier in insect population development. Among the IGRs, juvcnoid insect growth regulators kinoprene and fenoxycarb were found effective in managing the cotton aphid population in field and lab conditions (Satosh *et al.,* 1995). Buprofezin was also found effective in managing the mustard aphid population but effective only on immature stages and not on adults (Cock and Degheele 1998). So, the use of the IGRs in bio-intensive integrated pest management programmes could be effective in controlling aphids. Sometimes they might have a mild effect on natural enemies.

Use of botanical insecticides. Effective alternatives to synthetic pesticides for the management of insects include insecticidal plant extracts, which are a crucial part of sustainable integrated pest management (IPM) (Belmain and Stevenson 2001). The most significant commercial botanical pesticides are pyrethrum and neem-based products (Grzywacz *et al.,* 2014). Numerous Botanicals have been found effective in managing the aphid population in both field and laboratory conditions, neem-based products at different concentrations, are found most efficient over other botanicals. Neem products like NSKE could also be used in combination with entomopathogenic fungi as well as with buprofezin which is an insect growth regulator. Extracts of aak (*Calotropis procera*), gul-e-daudi (*Chrysanthemum indicum*), garlic (*Allium sativum*) and knair (*Thevetia peruviana*) against mustard aphid on canola, found effective in controlling aphid population on aphid and canola (Akbar *et al.*, 2016). Caster-oil (2%) and Karanj oil (2%) were found effective in aphid management in field conditions. So, the use of botanicals could play an important role in bio-intensive integrated pest management.

CONCLUSION

From the above discussion, it may be concluded that there is an increasing interest in developing biological methods of aphid control, driven not only by the desire to reduce reliance on chemical pesticides for environmental and health reasons but also by the continuing expansion of insecticide resistance problems among aphids and the withdrawal of registration approval for an increasing number of insecticide active ingredients. So far, most success has been achieved with the use of hymenopteran parasitoids, but significant successes have also been achieved with the predatory coccinellids. Entomopathogenic fungi similarly have great potential within bio-intensive integrated pest management strategies, although there is no single criterion that guarantees their successful uptake, and difficulties to be overcome not only practical but economic, social, and political. The potential for achieving control of aphid damage by manipulating the physical and biological environment of the crop is enormous. This window of opportunity could be extended by combining biological control with other strategies such as the breeding of crop varieties with partial resistance to the pest and ecological manipulation of agricultural ecosystems to conserve and enhance natural enemy populations.

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