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Mini Review

Mustard Aphid and Crop Production

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Abstract

Mustard aphid, *Lipaphis erysimi* (L.) Kaltenbach (Homoptera: Aphididae) is the most notorious, cosmopolitan louse-like and obligate ectoparasite, which causes a bulk of the qualitative and quantitative loss of rapeseed-mustard crops. This article reviews the general overview of biology, damages, and the management of mustard aphids. Biologically, *L. erysimi* adults are soft bodies, varying in color mostly yellowish-greenish, small to medium-sized, globular, pear-shaped, manifesting wing dimorphism based on the resource availability. Plasticity in reproductive mode either sexually or asexually stimulated as an adaptive response to cope with seasonal fluctuations, maximizes the chance of survival from predators being outnumbering. Mustard aphid infested host plant in three major ways, firstly by sucking the plant phloem through stylets, the needle-like piercing-sucking mouthparts which manifest injury like curling and yellowing of the leaf, stunting and drying up of the plants. Secondly, by excreting a sticky substance (honeydew) on which 'sooty mold' growth, which blocks the process of photosynthesis. Thirdly, it causes secondary plant injury by transmission and dissemination of viruses including turnip mosaic viruses. The appearance, multiplication, and disappearance of mustard aphid are largely regulated by weather variations. Its prolific multiplication greatly thrives by cool, wet, and cloudy weather. The mustard aphid can be eschewed more so if the crop is sown before 20th October. Applications of the recommended dose of fertilizers, irrigation, resistant varieties are some cultural practices to cope with the aphid population. Natural enemies are effective and impressive nowadays for crop protection. Ladybird beetles viz., *Cocciniella septempunctata, Hippodamia variegata,* and *Cheilomones vicina* are active predators of this pest. Chemical control includes the application of systemic insecticides below the ETL (Economic Threshold Level). Some major insecticide includes are Imidacloprid 17.8% @ 0.25 ml/l, Thiamethoxam 25 WG @ 0.2g/l and Dimethoate 30EC @ 1 ml/l of water.

Keywords: mustard aphid; *Lipaphis erysimi*; biology; management; infestation

Introduction

Mustard aphid, known as turnip aphid (*Lipaphis erysimi*) is one of the most serious destructive cosmopolitan pests, eternal annual imperils on Rapeseed-Mustard (*Brassica* spp) crops. *L. erysimi* (Kalt.) is distributed globally (Martin 1983; Pradhan and Moorthy, 1995) and is known as a worldwide key cruciferous pest (Atwal et al., 1976) including cauliflower, turnip, kohlrabi, radish, Chinese cabbage, Brussels sprout, broccoli, kale and a minor pest of the bean, beet spinach, pea celery, onion, stock, cucumber and potato (Scmutterer, 1978). It is a short-bodied, yellowish and green or greenish colored species measuring 2-2.5 mm length when they are fully grown. The adults may be wingless (Apterae) or winged (Alate) with two pairs of hyaline wings. The fifth abdominal segment bears a pair of cornicles. The winged adults usually have black body markings and blackish head. They are observed mainly on the growing points of the host plants such as tips, blossom, and immature pods, plus occupied almost the whole plant with a high population (Nelson and Rosenheim, 2006). They suck sap from the host-plant through the help of phloem sieve element, stylets, the needle-like piercing-sucking mouthparts, and infested plants eventually become stunted and distorted. Their major infestation symptoms including wilting, yellowing, and stunting of plants (Khan et al., 2015). The avoidable yield losses at anywhere owing to aphid infestation in the tune of 20 to 50%, and it could be extended up to 78% (Prasad and Phadke, 1983). As a result, it has been considered as the key pest status in the brassica family due to its prolific multiplication, the plasticity of reproductive mode, and heavy crop yield losses. The objective of a review is a general overview of biology, climatic condition, extend of yield losses and damage, range of host plant, and management.

Taxonomic Position of Mustard Aphid

Kingdom: Animalia
Class: Insecta
Sub-Class: Pterygota
Division: Exopterygota
Order: Homoptera
Family: Aphididae
Subfamily: Aphinidae
Genus: *Lipaphis*
Species: *Lipaphis erysimi* Kalt.

Biology and Life Cycle

Aphids depict fluid in reproductive mode-either asexually or sexually and are regarded as an adaptive response to cope with a climactic variation (Ogawa and Miura, 2014) Reference to Sidhu and Singh (1964), the aphid emergence initiates in the field 1st week of November and endure till the harvest. The females (stem mothers) travel from hills to plains, first reproduced sexually, and subsequently, their progeny produce nymphs parthenogenetically.

Parthenogenetic viviparity – a phenomenon that curbs oblige for males to fertilize females and slashed the egg stage of the life cycle. Strikingly, aphids reproduce clonally and give birth to young, and even the embryonic development of an aphid initiates before its mother's birth, succeed to telescoping of generations. All these peculiar traits aid aphids to frugal in energy and embark for short generation times. Such a prolific multiplication rate becomes glaring in exceptional high aphid progeny under suitable conditions. Moreover, the aphids are capable of depicting winged dimorphism to yield highly fecund wingless morphs or less prolific winged progeny that can diffuse to new host plants based on resource availability. The wingless ones are considerably copious, while winged forms are developed under high aphid densities, or when the host-plant quality is inferior. All these capabilities endow to aphids' success.

Eggs

Eggs are laid along the veins of leaves (Kawada and Murai, 1979).

Nymphs

Generally, mustard aphids have four nymphal stages (instars). The general appearance of each stage is almost alike aside from the increase in size during succeeding instars. The first, second, third, and fourth nymphal stages utmost 1-2, 2, 2, and 3 days respectively (Sachan and Bansal, 1975), and hence the nymphal stage endures for 8-9 days as a whole. During these durations, modest variations that come about actually on winged and wingless forms while nurturing on cabbage, cauliflower, mustard, and radish (Sachan and Bansal, 1975).

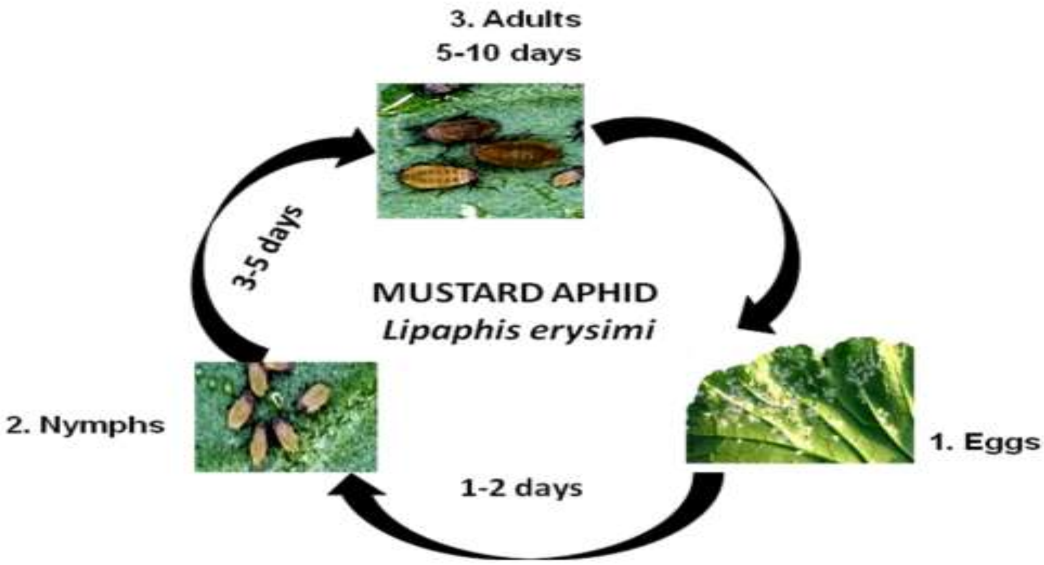

Fig. 1: The lifecycle of Mustard aphid

Adults

The characteristics appearance of the mustard adult aphid is a minute, globular, pear-shaped, soft, and fragile body, found with both winged and wingless ones. Wingless female aphids (known as apterae) are varying in color mostly yellowish-green, gray-green or olive green covered with the white waxy coating with green bands on the top of the body whereas, the winged, female adult aphids (known as alate) have a green abdomen with dark lateral stripes dividing the body segments and dusky wing veins (Blackman and Eastop, 1984). The waxy coating is more likely thick under humid conditions. Winged ones have transparent homogenous wings.

Antennae are dark (Deshpande, 1937). The apterae females are approximately 3/50-1/10 inch (1.2-2.4 mm) long, whereas the alate forms are close to 3/50-1/12 inch (1.4-2.2 mm) long (Blackman and Eastop, 1984).

The adult females initiate producing progeny even 1-2 days pass before, since complete the last molt (Sachan and Bansal, 1975). They endure reproducing progeny for 13-20 days pursuing a 2-3 days post-reproductive stage. Sachan and Bansal (1975) reported that that wingless females bear 70-87 progeny in their whole lifetime, while winged females bear 31-40 progeny respectively. The period of the adult stage is 26-37 days.

The features of Male aphids are olive-green to brown. They are greatly smaller than the females and are about 3/50 inches (1.20-1.35 mm) in length (Kawada and Murai, 1979).

Range of Host Plant

Mustard aphid is remained active for over a year, nonetheless, its intense activity period coupled with the growing period of cruciferous crops from September until March. During the slack period, the mustard aphids switch to wild or cultivated off-season crucifers in damp places in orchards and kitchen gardens (Sidhu and Singh, 1964). Various off-season hosts have been reported for this aphid including Asvagandha (*Withania somnifera*) from May to July, cauliflower (*B. oleracea*) from August to March, cabbage (*Brassica oleracea* var. capitata), Indian mustard (*Brassica juncea*), and radish (*Raphanus sativus*) from March to April, (Chandra and Kushwaha, 1987).

Economic Threshold

The aphid density at which management action should proceed to preclude an increasing aphid population from reaching the economic injury level (Table 1).

Crop Yield Loss

Infestations of *L. erysimi* on Indian mustard (Brassica juncea) were accountable for reductions on growth and yield parameters including plant height, the number of branches per plant, silique per plant, grain per silique, seed yield, oil content, and oil yield (Malik and Deen, 1998). It is empirically estimated that mustard aphid directly causes reduction to nearly 66-96% in yield losses (Singh and Sachan, 1997) to 75.70% (Sekhon et al., 1996) and further observed ranging up to 96 percent yield loss and 5-6 % reduction in oil content (Shylesha et al., 2006). These losses may extend up to 100% in certain mustard growing areas (Aamir and Khalid, 1961; Singh and Sachan, 1999). Reportedly, *L. erysimi* could be infested to the crop directly throughout seedling to maturity with the highest population occurring at the flowering/pod formation stage along with the seed yield reduction up to 90.3 percent during severe infestation (Verma and Singh, 1987). Malik et al. (1998) opined that loss in yield owing to the aphid in Indian mustard was up to 94.5%. However, in the susceptible varieties, the losses were estimated in the range of 38.2 to 46.56% against 2.86 to 17.53% in the resistant varieties (Singh et al., 1983).

Damage and Symptoms

It is a sap-sucking and obligate ectoparasite on the younger parts of the plant. The nymph and adults prevalently feed on sap from various parts of the plant above ground including leaves, young shoots, inflorescence, and young pods, ensuing in chlorophyll reduction or even plant mortality (liu and Yue, 2001).

Table 1: Economic threshold of *L. erysimi* under various crop/variety

Crop/variety	Economic threshold	Reference
B. campestris	9-19 aphid/ central shoot and 20% infestation	Singh et al., 1982
B. napus (GSL-1)	4 aphid/central shoot and 10% infestation	Rohilla et al., 1990
B. juncea (RL 1359)	9 aphid/ central shoot and 20% infestation	Rohilla et al.,1990
Mustard	9-13 aphid/15 cm top terminal	Singh and Mishra,1986
Brown sarson	4 mm shoot infestation	Suri et al.,1986

[Source: Jain and Bhargava, 2007]

Aphids affect plants in three major ways. Firstly, it induces damage straight by sucking the phloem from the several parts of the plants (Ali and Rizvi, 2007) with help of phloem sieve element, stylets, the needle-like piercing-sucking mouthparts, which eventually exhibits symptom of yellowing, curling, and consequent drying of leaves, the plant growth remains dwarf and stunted, which finally results in the formation of weak pods and undersized seeds. Feeding by *L. erysimi* hinders normal heading, blossoming, seed formation, and therefore seed yield and quality decline. The symptoms of pods damage are manifested by their thinning, curvature, and beyond than normal constrictions on them. In the case of the flower, in the initiation of infestation color of the flowers fade, and subsequently become white and at last, the petals wither.

Secondly, Since, phloem is an amino acid poor substrate, aphid elevated consumption levels of phloem sap to protein synthesis and produce offspring with a conversion of their abdomen into a filter chamber, aphids can shunt abundant phloem which is excreted in a sugar-rich sticky waste (honeydew) drips onto leaves, that encourage a fungus called sooty mold growth and subsequent leaves become dirty black (Awasti, 2002) and thick that acts as a barrier that restricts normal physiological metabolism and process of photosynthesis (Santos et al., 2013). Thirdly, Aphids are also correlated with secondary plant injury through acts as a vector for the transmission and dissemination of about 10 non-persistent plant viruses during feeding, encompassing cabbage black ringspot and mosaic diseases of cauliflower, radish, and turnip (Blackman and Eastop, 1984).

A colony of Aphid can once be conspicuously congregating on the abaxial surface of leaves or in the inflorescences (flowers) (Blackman and Eastop, 1984). Two sides of leaves are affected later on severe infestation (Yadav *et al*., 1988). On mustard, aphids opt for flowers to leaves (Singh et al., 1965). Apart from this, based on symptoms manifestation, aphid infestation indices were estimated as reported by Bakhetia and Sandhu (1973). Aphid infestation index: The scoring of plants measured depending on the following grade:

1. No aphid infestation plant manifests excellent growth. Albeit a single aphid was found on tender parts of the plant viewed as infested.
2. Normal plant growth, the leaf has not curled but varied in color from greenish to yellowish of leaves apart from a couple of aphids together with few symptoms of injury, good flowering, and pod setting on virtually all twigs.
3. Average growth of the plant, leaf form got curls, and yellowing of a couple of leaves average flowering and pod setting on virtually all the twigs. Few aphid colonies found on a couple of twigs and topical shoot
4. Growth less than average, curling, and yellowing of leaves on some branches. Plant manifest few cease the growth. The lower number of flowering and less pod setting aphid colonies on virtually all the twigs.
5. Plant growth was very weakened and stunted, the abundant number of curling and yellowing of the leaves, only a few flowering and pods setting. Outnumbering aphid population on plants.
6. Heavy infestation damaged plant growth becomes a virtually stunted condition, curling leaf manifest crackling and yellowing of virtually all the leaves. No flowering and pod development at all and plant ample of aphid.

Climatic Conditions

Weather variables influence the appearance, multiplication, and disappearance of mustard aphid (Vekaria and Patel, 2000). Multiplication of *L. erysimi* is thrived by cool, wet, and cloudy weather (Hasan et al., 2009). Several climatic attributes like fog, frost, rain, and high temperatures have been realized as main mortality factors of mustard aphid

Temperature

The peak incidence of *L.erysimi* takes place at a mean temperature of 17–18°C (Bishnoi et al., 1992). Severe cold during December and increasing temperature onward March preclude its multiplication. Its incidence during the flowering stage was positively correlated to a maximum temperature in the range of 20–29°C in the preceding week (Chattopadhyay et al., 2005). Specifically, the aphids exhibited higher prolific multiplication, net reproductive rate, and longer average generation time at 25°C than to a range of other temperatures tested (Hsiao, 1999). Kulat et al. (1997) uncovered that maximum temperature and minimum temperatures in the range of 26.4–29.0°C and 8.4–12.6°C coupled with relative humidity (RH) of 75–85% in January rendered the congenial conditions for aphid multiplication, but its population began to decline at RH ≤65%.

Humidity

Relative humidity ranging from 65–83% positivity correlated with the fecundity of mustard aphid. Although, its response on aphid progeny during the crop season, i.e. mid-January to mid-March, was proved to be statistically insignificant. The incidence of mustard aphid on the inflorescence of plants was positively correlated to RH (Samdur et al., 1997; Chattopadhyay et al., 2005; Narjary et al., 2013) with morning RH >92% and daily average RH >75% favorable for population multiplication.

Rainfall

However, Heavy rainfall has a profound effect on the mustard aphid population declining, build up within 1 week during the spring season. Bakhetia and Sidhu (1983) found that the endure rainfall for 4–5 days towards the end of

February outcome rapid mortality of this pest, which halt population development in the following weeks. Even mild rainfall was reported lethal effect on population built-up (Hasan et al., 2009).

Management

A. Cultural practices

Time of Sowing

Aphid progeny and the rate of infestation are directly positively relying on sowing time (Islam et al., 1991). Alteration time in crop sowing can eschew phenological synchrony between the most sensitive stages of species with the peak period of insect infestation. This asynchrony can also be realized through genetic engineering by inserting genes for earliness and lateness in the crop. The flowering period (end of December, the first fortnight of January to mid-February) is the critical period for aphid infestation. Hence, the crop is sown early before 20 October predominately eludes aphid infestation (Ghosh and Ghosh, 1981; Kular et al., 2012) since plants become hardy before the peak period of infestation (Singh et al., 1984; Singh and Bakhetia, 1987). Pal et al. (1976) also reported that the aphid infestation was the main reason for yield loss in late sown crops.

Nutrient application

Heavily fertilized crops are often susceptive to the incidence of the population of *L.erysimi*. Hence, aphids feeding on host plants obtained higher nitrogen doses certainly had shorter nymphal developmental time, longer adult longevity, and higher fecundity (Fallahpour et al., 2015). Pandey (2010) reported that the aphid population to surge dramatically with the application of sole nitrogen or higher levels of nitrogen. While the application of phosphorus and potash whether or not with a combination of nitrogen limits the population incidence. Hence, Balanced and judicious plant nitrogen fertilization for crops to some degree serves as a pest management tool.

Resistant varieties

Genetic resistance against mustard aphid can be realized through breeding techniques and tools by incorporating resistance genes from sexually compatible germplasms. For instance, S.p ray (1998) reported that toria lines namely, ICT-9135, TS-72, TL-15, Acc-6790, Acc- 12-31637, Acc-17-31642 and Acc 32-31893; Sarson line LSS-9305, while mustard varieties including Krishna, Kranti, Varuna, Pusa bold and BR-40 were found to tolerant against mustard aphid

B.-Botanical Control

Several plant materials as extracts have been assessed against mustard aphid, namely nicotine sulfate, rotenone, and pyrethrins. All these have shown variable toxicity. Plant extracts of *Azadirachta indica, Lantana camara, Ipomoea carnea, Acorus sp., Solanum xanthocarpum, Swertia chirata, Melia azedarach, and Argemone maxicana* found to be toxic against mustard aphid (Pandey et al., 1977). In a field trial on the mustard crop (*B. juncea*), thermo and photostable tetrahydroazadirachtin-A proved an effective control of mustard aphid as compared to azadirachtin, apart from being safe to natural predatory arthropods (Dhingra et al., 2006). Singh (2007) found that neem seed kernel extract (5%) and neem leaf extract (5%) superior control against mustard aphid.

C.-Use of natural enemies

Bakhetia and Sekhon (1989) noted six species of coccinellids, 16 syrphids, one chamaemyiid, hemerobiid (predators), four species of hymenopterous parasitoids, four species of entomogenous fungi, and one predatory bird to be correlated with mustard aphid as natural enemies. Coccinellids are the chief predators of mustard aphid with a couple of species including *Coccinella septempunctata, C. repanda, C. transversalis, Brumoides suturalis, Menochilus sexmaculatus, and Hippodamia variegata,* realized to be copious in the brassica agroecosystem. Even with their abundance, these natural enemies fall short in satisfactory control of mustard aphid. As the matter of fact that aphids thrive at temperatures below 20°C, while coccinellids thrive above 20°C, eventually lead to phonological asynchrony in their peak periods of activity, perhaps, considered as one crucial reason is even supported by Sarwar (2009), who concluded a lack of synchronization between populations of mustard aphid and its predators on canola rape. *Coccinella septempunctata* at 5000 beetles/ha and *Verticillium lecanii* at 108 conidial spores/ ml were proved significantly superior in declining aphids number on Indian mustard 10 days after release (Singh and Meghwal, 2009). Syrphids also found predating upon the mustard aphid. Despite this, their abundance is comparatively low and have a constraint for the control of mustard aphid. Moreover, it is reported that syrphids oviposit mainly when their prey population reaches a certain threshold level, for instance, Luna and Jepson (2003) found that syrphids do not oviposit before aphid infestations surpass 50 aphids per broccoli plant. Besides that, the green lacewings *Chrysopa scaslastes* and *Chrysoperla carnea* also reported effectively prey on the mustard aphid. Even though, their scope in population control of insects is very confined. Among the parasitoids, *Diaeretiella rapae* and *Encyrtus* sp. have also been observed parasitizing the mustard aphid. *D. rapae* had been reported to be an effective parasitoid of aphid, which showed in more than 70% parasitization (Atwal et al., 1969).

Table 2: A recommended insecticide with dose and water required in liter/acre

Insecticide	Dose/acre	Water required in liter/acre
Chlorpyrifos 20 % EC	200ml	200-400L
Dimethoate 30% EC	264ml	200-400L
Malathion 50% EC	400ml	200-400L
Methylparathion 2% DP	6000g	
Monocrotophos 36% SL	150ml	200-400L
Oxydemeton–methyl 25% EC	400ml	200-400L
Phorate10% CG	4000g	
Phosphamidon 40% SL	200ml	200L
Thiamethoxam 25% WG	20-40g	200-400L

[Source: Department of agriculture and cooperation, Ministry of Agriculture, Government of India]

D.-Chemical control

Admittedly, If the aphid population surpassed through action thresholds or the natural enemies unable to cope with the rapid intensify aphid population, then different insecticide treatments are mandatory for effective control (Jain and Tiwari, 2017). Injudicious spraying of chemical insecticides dire warning of agro-ecosystem vulnerability, which is a leading concern about their use. That's why selective insecticidal treatments have been studied and recommended by several workers every so often against mustard aphid in various regions of global (Table 2).

The chemical pesticides are found in two forms, i.e contact, and systemic insecticides. Since they frequently infest the abaxial surface of the leaves and sucking through inserting stylets directly from the phloem sap, aphids are barely succumbing with contact insecticides. Importantly, Systemic insecticides which are directly assimilated by the plants, are primarily used and well known to control aphids, as it is sucked through phloem sap and kill the aphids regardless of their shelter and feeding even if under the leaf. The predominate agrochemicals employed in the control of aphids such as carbamates, organo-phosphates, pyrethroids, cyclodienes, etc. group of insecticide (Bahlai et al., 2010, Cameron et al., 2005). Aphids progeny builds up resistance against the normally sprayed organophosphate group of insecticides (Gould, 1996).

Conflict of Interest

The author declares that there is no conflict of interest with a present publication.

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