Journal of Oilseed Brassica, 15 (1) : 26-32, January 2024

Review Paper

Mustard aphid: identification and control strategies

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(Received: 18 December 2023; Revised: 26 December 2023; Accepted: 30 December 2023)

Abstract

Indian mustard is more susceptible to insect pests than other oil seed crops due to which insect pests becomes the major factor in its low yield. Mustard aphid, Cabbage aphid, Mustard sawfly, Cabbage butterfly, Painted bug, Mustard leaf eater, leaf miner, thrips and whitefly are the pests causing damage to the mustard crop. Among all these pests, mustard aphid (*Lipaphis erysimi* Kalt.) is the most destructive pest in India. Being an obligate ectoparasite it causes a bulk of the qualitative and quantitative loss in rapeseed-mustard crops. The adults of mustard aphid are soft bodied and vary in color. They are mostly yellowish-greenish, small to medium-sized, globular, and pear-shaped, with distinct wing dimorphism on the basis of availability of resources. Mustard aphids harm crops by sucking plant sap, causing visible damage like leaf curling and yellowing. They also excrete honeydew, leading to sooty mold that hampers photosynthetic activity of the plant, and contribute to virus transmission like turnip mosaic virus. A weather variation plays an important role in appearance, multiplication, and disappearance of mustard aphid. Cold, rainy, and overcast weather promotes its profuse multiplication. Some cultural techniques to manage the aphid population include fertilizer applications at the recommended dose, irrigation, and resistant cultivars. Natural enemies are beneficial for crop protection nowadays. *Coccinella septempunctata, Hippodamia variegata*, and *Cheilomenes vicina* are active predators of this pest. The mustard aphid population can be kept below Economic threshold level by using systemic pesticides like Imidacloprid 17.8SL @ 0.25 ml/l, Thiamethoxam 25WG @ 0.2 g/l and Dimethoate 30EC @ 1 ml/l of water. This article reviews the general overview of identification, biology, life cycle, nature of damage, population dynamics and different management practices of mustard aphid.

Keywords: *Mustard aphid, management, rapeseed-mustard, yield loss*

Introduction

Although rapeseed is treated as a single commodity in agriculture and the food industry, the crop is made up of seeds from two or three different species (Pechan and Morgan, 1985). In Asia, plants like *Brassica rapa* and *B. juncea*, Indian mustard is an old plant, known as a spice since 3000 BC in Sanskrit and Sumerian texts (Hemingway, 1995). Mustard oil is one of the healthiest edible oils because it is low in saturated fats and has no trans fats. It also contains a lot of mono- and polyunsaturated fats, as well as omega-3 fatty acids (Das *et al.*, 2009). Different insect's pest complex, that damages the crop and deteriorates crop production were found in mustard. The aphid's major activity period is from September to March, which coincides with the growing season for cruciferous crops, however it is active all year. During its lean season, the aphid switches to wild or farmed off-season crucifers in wet areas, orchards, and kitchen gardens (Sidhu and Singh, 1964). Aphids cause severe damage to plants by sucking plant sap from young shoots and flowers at first, and then sucking sap from tender pods later. Due to the excessive honeydew secretion by aphid on the foliage, the plant gets weak and stunted. It causes the growth of black sooty mold, which obstructs the leaves' photosynthetic function (Chaudhary and Pal, 2006). It is a widely distributed insect that can be found on both the leaf surfaces and the leaf folds of developing heads (Sachan and Bansal, 1975). Aphids have been found to have a variety of off-season hosts. From May to July, Ashwagandha (*Withania somnifera*), cauliflower (*B. oleracea*), cabbage (*Brassica oleracea var. capitata)* and radish (*Raphanus sativus)* are some of them. The most damaging pest of rapeseed mustard is the mustard aphid (Das, 2002). It's also on the stalks and axils of the leaves. Primarily found on the host plant's growing points, such as tips, flowers, and developing pods, and then covers the entire plant (Nelson and Rosenheim, 2006). It causes 35 - 75% reduction in yield (Rana, 2005) and a 6% reduction in oil content (Singh *et al.*, 1987). Quick aphid multiplication requires a minimum temperature in the range of 4 - 13.8°C. A mean maximum temperature ranging from 14.0°C - 30.0°C with a relative humidity of 48 - 80% (Sekhon and Bakhetia, 1994). Aphids are said to be affected by rainfall. Mild rainfall helps the aphid population multiply when the mustard is in the flowering stage (Singh *et al.*, 1990). Aphids are completely eliminated when the crop is in the pod stage. Aphid infection can result in yield losses of 20 to 50 percent, and as high as 78% in some cases (Prasad and Phadke, 1983). Vekaria and Patel (2000) reported that the presence, multiplication, and disappearance of aphids are all influenced by the weather. Some aphid species growth slows as a result of higher temperature, thermal requirements, and host specificity (Singh *et al.,* 2008).

Identification

The adults of *L. erysimi* are small to medium-sized and yellowish green, gray green, or olive green color with a thin white wax coating. The thorax and abdomen have two rows of dark bands that merge into one near the tip of the abdomen. The siphunculi have dark tips and are pale (Singh *et al.,* 2008). Apterous adult of *L. erysimi* have a body length of 1.4 - 2.4 mm (Prasad and Phadke, 1983). There is a distinction in size and shape between nymphs and adults. Nymphs in their first instar are wingless, translucent, yellowish-green, and oval. Second instar nymphs are oval and greenish yellow. Third instar nymphs are longer and wider. Fourth instar nymphs are noticeably larger in size, featuring a yellowish-green abdomen (Sachan and Bansal, 1975). This may be due to variations in nutrients from host genotypes. Adults resemble last instar nymphs, with long antennae and prominent cornicles. The length of apterous adults ranges from 1.25 to 1.83 mm and the width varies from 0.55 to 1.08 mm.

Biology and life cycle

Mustard aphid *L. erysimi* reproduces in two ways: sexual reproduction, which involves males fertilizing females, and parthenogenesis, which involves females giving birth to nymphs without fertilization. Males are extremely rare, and females are almost always viviparous throughout the year, with males being seen only during the cooler months (Kawada and Murai, 1979). At 16-18°C temperature, maximum reproductive rates were found than at 24-25°C (Wu and Liu, 1993). From January to March, the aphid was observed to be reproducing only through viviparous parthenogenesis. During this time, the aphid produced eight generations on average, with two coexisting in January, three in February, and three in March (Dwivedi *et al.*, 2018). Antioxidants and tannins have significant effects on progeny production and survival of mustard aphid on *B. juncea.*

Eggs

Eggs are white in color and lay along the veins of leaves.

Nymphs

There are four stages of nymphs. Each stage of the mustard aphid has a similar appearance, but the size of the instars grows larger. The 1st, 2nd, 3rd, and 4th nymphal stages each last between 1-2 and 3 days which gives the nymphal stage an overall duration of 8-9 days.

Adults

Wingless, female, aphids (called aptera) are yellowish green, gray green or olive green with a white waxy bloom covering the body. The waxy coating is solid under humid conditions. The winged female and adult aphids (called alate) have a dusky green abdomen with dark lateral stripes separating the body segments and dusky wing veins (Blackman and Eastop, 1984). Antennae are dark in color except at the base (Deshpande, 1937). The apterae females are about 1.2-2.4 mm long and the alate forms are about 1.4-2.2 mm long (Blackman and Eastop, 1984).

Nature of damage

Aphids damage the plants by sucking cell sap and large colonies causes the plants to become deformed resulting in the leaves becoming curled, shriveled and yellowed (Metcalf, 1962). The mustard aphid normally found in large numbers on the undersides of leaves or on inflorescences. In severe infestations, both sides of leaves are infested (Yadav *et al*., 1988). Aphids prefer flowers to leaves (Singh *et al*., 1965). It produces honeydew which serves as a medium on which a sooty fungus grows, called sooty mould. Liu and Yue (2001) reported that it is a sap sucking, obligate ectoparasite on the tender parts of plants. The nymph and adults predominantly feed on the sap from the leaves, young shoots, inflorescence and young pods, resulting in chlorophyll reduction or even lead to plant mortality. It was yellowish-green having a somewhat roundish abdomen. This might be due to variation in nutrients supplied by host genotypes on which aphid was reared. Adults looked more or less similar to last instar nymph.

Symptoms

Yellowing, curling, and ultimately drying of leaves appear as a result of extensive infestation, resulting in fragile pods and little seeds in the pods. It also secretes honeydew, which causes the growth of sooty mold and lowers the photosynthetic rate (Sekhon, 1989). At severe attack chemical control is the only choice to deal with the outbreak of mustard aphid.

Population dynamics

Climatic factors like temperature, humidity, rainfall, wind speed, and cloudiness have a significant impact on mustard aphid growth. The accumulation of growing degree-days starts on December 1st (Dhaliwal *et al*., 2007). Favorable conditions for population growth include ambient sunshine, maximum temperatures, and relative humidity. However, activity stops at lower relative humidity levels. Aphid incidence begins in January and peaks in February (Biswas *et al.,* 2000). Similarly, (Kulkarni *et al.*, 2001) the population of aphids is affected by temperature, humidity, rainfall, and hailstorm. The peak population of aphids per plant varies across different years. Mustard aphid incidence starts in November and peaks in January before dispersing in February. Aphids first emerge on leaves and then on inflorescence (Bapari *et al.,*2007). Infestations begin in December and peak in February. Mustard aphid population growth starts in December, peaks in the third week of February, and then declines (Chander *et al.,* 2011). There is a positive association between aphid population and temperature, but has little reaction to rainfall (Reza *et al*., 2004; Vekaria and Patel, 2005).

Management practices for *Lipaphis erysimi*

Cultural control

Considerable experimental evidence is available in Indian literature on the usefulness of cultural and agronomic practices such as timely sowing, sanitation, ploughing, crop rotation, intercropping, spacing and nutrient management in minimizing the losses due to pests in mustard (Saljogi *et al.,*2009). Early October sowing (Kolte, 1985), balanced NPK application-100:40:40 (Sharma and Kolte, 1994) and sanitation are the important top priority practices in management of aphid infestation. Khurana (1986) reported the incidence of mustard aphid more on late sown than early sown crops. Similarly, Upadhyay (1993) observed the greater incidence of aphid in delayed sowing at all stages of crop growth. The peak aphid incidence attained earlier in late sown and later in early sown crop. Kumar (2004) observed the population of *L. erysimi* higher in early planted mustard as compared to the timely sown crop. The aphid appeared during the 4th week of November in early planted mustard and reached its peak (8.9/twig) during the 3rd week of December and then declined during the 4th week of January. Patel *et al*. (2004) reported that the aphid was found to be the maximum during the 3rd week after aphid appearance when the crop was in flowering stage. There was not much difference in aphid population in the crop sown up to the end of November and in December. *L. erysimi* appeared immediately after germination and reached its peak during the 2nd week of March on *B. campestris.* Early date of sowing was best to avoid aphid as compared to timely and late date of sowing (Dhaliwal *et al*., 2007). Singh *et al*. (2007) conducted field experiments during *Rabi* season taking three sowing dates *i.e.*, 5th October, 19th October and 24th October. Early sown *B. juncea*, the aphid population exhibited negative correlation with the morning and evening relative humidity and rainfall (Hugar and Pratiba, 2008). They divided the aphid infestation period into 3 different phases, the establishment phase, the weather parameters had a significant role in governing the aphid population. The temperature, rainfall and sunshine hours were negatively correlated, whereas, the morning and evening relative humidity and wind speed positively correlated. During the decline phase, the wind speed along with temperature and relative humidity had a negative relationship. Shah *et al*. (2015) studied the effect of biotic and abiotic factors on population dynamics of mustard aphid on late sown mustard crop during 2012-13 and reported that the population of mustard aphid and its predator *C. septempunctata* appeared from 10th December to 3rd March. Peak infestation of *L. erysimi* (29.12/plant) was recorded on 21st January and remained higher throughout the January and decreased in February. Regarding *C. septempunctata* population reached its peak (13.14/plant) on 3rd March and remained lower under low temperature and as the temperature increased, there was a simultaneous increase in population of *C. septempunctata.*

Biological

Natural enemies of mustard aphid, *Coccinella septempunctata* (Coleoptera: Coccinellidae) is an aphidophagous beetle that feed upon aphids; *L. erysimi, Brevicoryne brassicae, Acyrthosiphon pisum, Schizaphis graminum, Hydaphis coriandri, Aphis gossypii, Melanaphis sacchari* and *Rhopalosiphum maidis* infesting mustard, cabbage, cauliflower and wheat (Indu and Chatterjee, 2006). Rana *et al*. (1995) reported that the population of *C. septempunctata* first appeared on mustard during the month of December, its population increased gradually to attain peak population of 10.70/plant by the end of December (52nd SW) followed by a sudden decreased in the end of January (4th SW) which was mainly due to the low temperature (Penrez and Omkar, 2005). The population again increased up to 18.00/plant in February (8th SW) which decreased the population of aphids. Bisht *et al*. (2001) studied the seasonal occurrence of four species of Coccinellids viz., *Coccinella septempunctata* (L), *Hippodamia variegata* (Goeze), *Harmonia eucharis* (Mulsant) and *Adonia spp*. and one *Syrphus* spp. and one species of *Aphidius matricariae*, parasitoid of *L. erysimi* from Garhwal hills. Singh *et al*. (2003) reported the relative abundance of the effective natural enemies of mustard aphid, *L. erysimi*, during 2000-01, 2001-02 and 2002-03 and noticed the highest population (41.97%) of *Coccinella septempunctata* followed by *Coccinella transversalis*, *Diaeretiella rapae, Chrysoperla carnea*, *Menochilus sexmaculatus*, *Ischiodon scutellaris* and *Brumoides suturalis* with 25.03, 11.78, 7.64, 6.00, 3.93 and3.65% relative abundance, respectively. Talpur and

Khuhro (2004) reported the predator species such as *Chrysoperla carnea*, *Coccinella undecimpunctata* and *Coccinella septempunctata* appeared when the population of mustard aphid was sufficiently developed on the rapeseed-mustard. Vekaria and Patel (2005) observed the first appearance of braconid endoparasite, *Diaeretiella rapae* on *L. erysimi* during the 3rd week of January and attained its peak during the last week of February. They also reported that the predominant predator *Coccinella septempunctata* was active from last week of January to last week of February with maximum population (up to 5.52 beetles/plant) during 3rd week of February. Rana (2006) noticed that the response of two ladybird species, *Coccinella septempunctata* and *Menochilus sexmaculatus* was dependent upon density and time of appearance of their prey, *L. erysimi*. They reported the first appearance of mustard aphid during the 2nd (2000-2001) and last (2001-02) week of January whereas the ladybird beetle's eggs in the last week of January, 4-5 weeks before the maximum aphid population. Eggs and larvae showed a significant positive correlation while adult beetles showed non-significant positive correlation with aphid population (Chakravarty *et al.,* 2004). Dogra *et al*. (2003) reported the first appearance of *D. rapae* on L. *erysimi* in the 2nd week of January which gradually increased and attained maximum parasitization (51.07%) in the 2nd week of March when mean maximum temperature, mean minimum temperature and relative humidity were 22.5°C, 10.3°C and 36%, respectively. They also reported that temperature, relative humidity and rainfall had no significant impact on the population build-up of both *L. erysimi* and *D. rapae*. Correlation coefficient between relative humidity and aphid (r = -0.52) as well as with its parasitoid, *D. rapae* (r = -0.59) shows significant negative correlaton whereas, day (r= 0.65) and night temperature (r= 0.61) had significant positive correlation (Pawar *et al*., 2010). The *D. rapae* was positively correlated with maximum and minimum temperature and bright sunshine hours. Achintya and Debjani (2012) and (Patel and Singh, 2016) observed the maximum number of mummified aphid population on BSH-1 followed by Varuna, GSC-6, *B. alba*, YST-151 and *B. nigra* while, T-27 and *B. carinata* with minimum number. The parasitism of *L. erysimi* by *D. rapae* was found lowest in T-27 (10.04%) and *B. carinata* (16.13%) while, highest in *B. alba* (45.68%) followed by YST-151 (25.83%), BSH-1 (23.22%), GSC-6 (23.04 %), Varuna (21.28%) and *B. nigra* (18.08%).

Bio-rationales

Pal *et al.* (2020) studied the effect of bio rational approaches for management of mustard aphid. The treatments were Azadirachtin @ 5ml/L followed by its second spray after 15 days, T_2: Azadirachtin followed by *Beauveria bassiana* @ 2g/L after 15 days, T_3: *B. bassiana* followed by its second spray after 15 days, T_4: Azadirachtin followed by *Verticillium leccani* @ 2g/L after 15 days, T_5: *V. leccani* followed by its second spray after 15 days, T_6: Dimethoate 30EC @ 1ml/L followed by its second spray after 15 days and T_7: Control. Out of which Dimethoate 30EC @ 1ml/L followed by its second spray after 15 days provided the highest seed yield which was higher than Azadirachtin followed by *V. leccani* after 15 days. Dimethoate followed by its second spray after 15 days was found most economic with highest benefit cost ratio as it gave the maximum benefit (1:37.6) which is very large as compared to remaining treatments and the next effective treatment was Azadirachtin followed by *V. leccani* after 15 days (1:12.5).

Cow urine has a unique place in Ayurveda and has been described in 'Sushrita Samhita' and Ashtanga Sangraha' to be the most effective substance secretion of animal origin with innumerable therapeutic values. As per Ayurveda literature, cow urine possesses many medicinal properties. Krishnamurthy *et al*., 2004; Chauhan *et al.,* 2001; Singh and Arya, 2004) reported 100% mortality of both nymphs and adults of mustard aphid with 4 per cent concentration of neem extract after 72 hours of treatment. Gupta (2005) reported that the incidence of mustard aphid can easily be managed by adopting 3 or 4 foliar sprays of neem kernel extract (in cow urine) 3% either alone or in combination with reduced dose of Dimethoate 0.03%. Hasan and Singh (2008) evaluated the bio-efficacy of cow urine decoctions of eight botanicals against mustard aphid and revealed that the highest toxicity was recorded in cow urine decoction of *Azadirachta indica* and lowest in *Aegle marmelos*. Hasan and Ansari (2012) observed that the cow urine decoctions prepared in neem leaves were found very effective against reduction of *Lipaphis erysimi* population under field conditions. Meena *et al*. (2013) revealed the efficacy of plant products (tobacco, onion and neem seed kernel extract @ 5%), cow urine @ 50 litre/ha and dimethoate 30 EC @ 300 g a.i./ha against mustard aphid and their safety to natural enemies and pollinators. Significantly higher aphid reduction was recorded under these treatments over the control without any phytotoxic effect and found safe to natural enemies of mustard aphid. Negi (2015) conducted bioassay studies on cow urine and cow urine-based neem and jatropha leaf and seed extracts @ 2% and found them very effective against female fecundity and mortality of mustard aphid on treated mustard inflorescence under laboratory conditions at Pantnagar. Yadav and Tiwari (2020) conducted a preliminary bioassay study on the bioactivity of cow urine based natural formulations such as cow urine, jeevamrit, neemastra, agniastra, dashparni, panchgavya @ 1%, 3% and 5% against preference, fecundity and mortality of mustard aphid and reported attractancy of mustard aphid towards neemastra and least attracting towards agniastra, dashparni and panchgavya. They also found them all very detrimental against aphids by increasing mortality and decreasing fecundity of gravid female aphids on mustard.

Chemical

The realm of pest management for mustard crops is undergoing a notable transformation as conventional insecticides make way for novel counterparts, placing increased emphasis on specificity, eco-friendliness, and the utilization of lower effective doses. Historically, insecticides like Phosphamidon, Dimethoate, and Methyl demeton have been stalwarts in the fight against mustard aphids, as recommended by Upadhyay and Agrawal (1993) and Prasad (1997). Rohilla *et al*. (2004) undertook a meticulous investigation into the bio-efficacy of ten insecticides against *Lipaphis erysimi*, singling out Imidacloprid, Thiamethoxam, Oxydemeton methyl, and Monocrotophos as particularly effective in mitigating the impact of mustard aphids. Supporting this line of inquiry, Singh and Velma (2008) identified Oxy-demeton methyl and neem leaf extract as potent deterrents, with applications of Oxydemeton-methyl and neem oil yielding significant aphid mortality and marked improvements in crop yield. A more nuanced exploration by Seni and Naik (2017) discerned the varying toxicity levels among insecticides, placing Chlorpyriphos at the forefront, succeeded by Imidacloprid, Ethiprole Imidacloprid, Thiacloprid, Pymetrozine, Lamda cyhalothrin, Acephate, and Fipronil. Lal *et al*. (2018) and Patel *et al*. (2020) delved deeper into the bio efficacy of Imidacloprid, Acetamiprid, and Thiamethoxam, emphasizing their effectiveness in controlling mustard aphid populations. In a notable study by Ramana *et al*. (2020), the concept of persistent toxicity was introduced, evaluating insecticides such as Methyl-O-Demeton, Spinosad, Acetamiprid, Chlorfenapyr, and Fipronil. Acetamiprid displayed superior mortality rates and persistent toxicity, positioning it as a promising insecticide for sustained control of mustard aphids (Sarkar *et al.,* 2008). This paradigm shift in insecticide research not only signifies a departure from traditional approaches but also heralds a more nuanced, environmentally conscious era in mustard aphid management, promising targeted and efficient pest control strategies for mustard crops.

Yield losses

Mustard aphid, *Lipaphis erysimi*, stands as a primary threat to rapeseed-mustard, significantly diminishing both the quantity and quality of crop production. Various studies, including those by Bakhetia (1983) and Singh and Sachan (1995), have reported losses ranging from 35.4% to 73.3% under diverse agro-climatic conditions, with instances of up to 100% yield reduction. Prasad and Phadke (1986) highlighted substantial losses, reaching up to 97.2% to 98.5% in toria, 84.2% to 98.9% in Brown sarson varieties, and 65.5% to 85.4% in rai varieties due to aphid infestations. Singh and Henry (1987) recorded losses ranging from 9.59% to 57.46% attributed to mustard aphid infestation, emphasizing the economic impact of this pest. Rouf and Kabil (1997) noted that without intervention, aphid infestation could lead to a drastic reduction of 30-90% in mustard yield. Sharma and Yadav (2000) observed a rise in aphid numbers during the flowering period, peaking at 283.9 aphids/10 cm top twig/plant, and linked delayed sowing to decreased seed yield. Patel *et al*. (2004) echoed the sentiment, asserting that mustard aphids, particularly *Lipaphis erysimi*, significantly curtailed the potential productivity of *Brassica juncea*. In an effort to quantify yield losses due to aphids in different thermal environments (Takar *et al.,* 2008). These findings underscore the critical need for effective control measures to mitigate the economic impact of mustard aphid infestations on crop yields.

Conclusion

Temperature is the most important abiotic component in the growth of mustard aphid populations. There are three primary components of the mustard aphid that need to be identified and appropriate forewarnings provided, like severity, the time when the aphid reaches the economic threshold population for pesticide application, and the time when peak population occurs. The development of insecticidal resistance, resurgence, pest outbreaks, and other issues with most commonly used broad spectrum insecticides in the field is a serious concern in chemical management. This has prompted the employment of alternative environmentally safe insecticides to maintain insect pest management, and resistance to these old insecticides can be overcome by employing the newer group of chemicals. The use of newer, safer insecticidal compounds in place of older formulations or other traditional insecticides can minimized the risk to natural enemies. Plants are rich in natural compounds and have a lot of potential for being turned into botanical pesticides that may be employed as environmentally safe replacement for synthetic insecticides. Insects and other herbivores are harmed by secondary metabolites found in plants in a variety of ways, including enzyme inhibition, acute toxicity and interference with food intake and/or use.

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