Chapter

Brassica-Aphid Interaction: Modulated Challenges and Sustainable Approach for Management

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Abstract

Insect pests act as main barrier in enhancing yield potential of Brassica crops. *Lipaphis erysimi* is considered as one of the most destructive insect species in mustard production due to its voracious type feeding and multiplication. Therefore application of insecticide is inevitable for cultivation of cruciferous crops, although systemic insecticides has been found to be suitable for management of aphid, despite of high cost, residual effect and ecological ramification have necessitated the application of bio and botanical insecticides as novel approach and are recorded significant in research. Aphids having exclusively viviparous parthenogenesis type reproduction from January to March month with the completion of eight generations are helpful in quick mass multiplication. Natural enemies *Coccinella* spp., Syrphid larvae and bio-pesticide found effective in suppress aphid numbers. Manipulation in sowing dates of mustard crop provides good yield and less incidence of aphid which is proved through research. Lack of environmental resistant varieties has dispensed toward non feasibility of conventional breeding approaches for developing aphid-resistant Brassica. Although application of genetic engineering plan has resulted in moderate success in development of aphid resistance, so far commercialization of such genetically modified crops has not conceivable, intimate the necessity of further insights in to host plant and aphid communication to form effective approach against aphid resistance. Therefore in this chapter the components involved in Brassica aphid communication are highlighted and present statuses and problem in aphid management are discussed.

Keywords: aphid, ecological factors, entomopathogenic fungus, predators, resistance varieties, systemic insecticide, yield loss

1. Introduction

Rape seeds-mustard act as a major valuable oilseed and create key commencement of utilisation of oil and cake for feeding purpose of human as well as animal respectively. It has crucial status in Indian recession. India ranked 2nd in the production of mustard among all oil seed crops followed by China [1]. Mustard shared total 26% of production of oil seed in India. Main component of mustard is oil (32–40%) and protein (15–17%) Oilseeds as dietary food on priority basis and stored as raw material in agro industry are used to prepare various commodity such as cosmetics, detergents, laxatives, soaps, lubricants, apart from it have excellent medical and therapeutic significant. Application of recent package of practices with the cultivation of high yielding varieties enhances production of mustard. Rape seed mustard are highly susceptible to incidence of several pests like mustard aphid (*L.erysimi* Kalt), painted bug (*Bagrada picta*), sawfly (*Athalia proxima*),) leaf minor *(Phytomyza atricornis*) and flea beetle (*Phyllotreta cruciferae)*, among, *L. erysimi* is most destructive deliberate pest of mustard. Aphid act as key crop pest due to its damaging capability of target crop in recent cropping pattern, It acts as alarming arthropod and spreaded globally including temperate and subtropical territory. Aphids suck phloem and chlorophyll tissues from tender portion of plants and causing qualitative and quantitative yield-limiting factor. Infestation of aphid decreases in the yield by reducing no. of pods/plant, no. of grains/pod and oil content within grains (**Figure 1**). Aphid has overcome the barrier of glucosinolates becoming involved in self protection against insects those feed on the phloem content and sequestering these compounds arresting them within body. Abiotic components such as temperature, light, moisture, wind velocity etc. express clear response on incidence as well as multiplication of aphid population, among them, temperature played significant role in multiplication of aphid and air current and rain fall were noted as significant factors for survival as well as dispersion of aphid [2]. Occurrence and intensity of aphid mainly gets in trouble by climatic factors. This pest remains active throughout the growth period of crop up to pod drying by consuming liquid content from tender vegetative portion, floweral parts and siliqua of mustard**.** Immature and adults stage feed on succulent vegetative and pod formation stages of crop resulting in stunted growth, wither floral parts and grains undeveloped in siliqua. Infested leaves become wrapped and discoloured, brownish marking develops on vegetative portion and show wilting symptom. *L.erysimi*

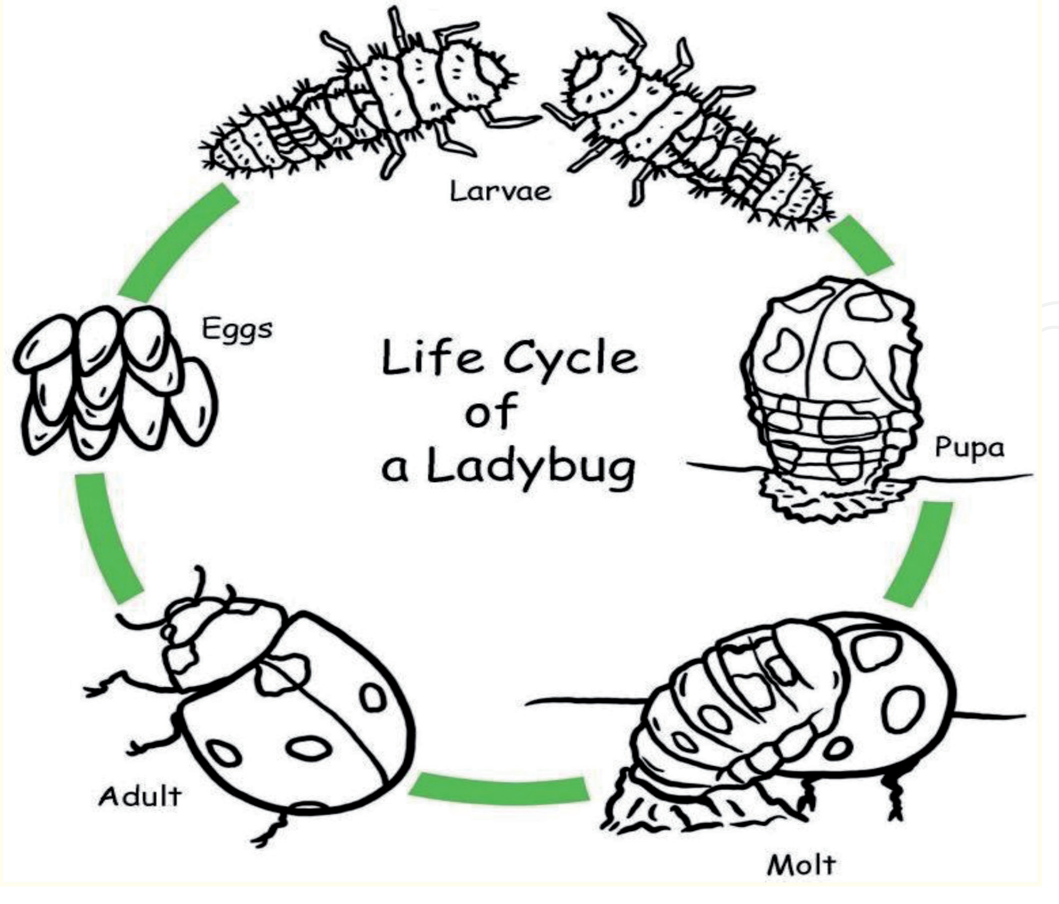

Figure 1.
Life cycle of predator Lady bird beetle Coccinella septempunctata*.*

release sticky sweet substance which develops sooty moulds as a result vegetative portion appears black patches and faces photosynthesize inhibition [1]. Mustard aphid caused 9%–95% production losses. In India at different locality aphid caused tremendous 83% loss in rapeseed and mustard 91.3% and 34.68% at Kanpur, 59.49% at Pant Nagar, 72.61% at Ludhiana, 29.43% at Navgaon. Regarding management aphid farmers rely up on the application of synthetic chemical that creates harmful condition like residual content of toxic substance, forming resistance against target pests and indiscriminate use of such chemical causes environmental pollutions, mortality of bioagents etc. To avoid such adverse things, finding out aphid resistance or tolerant cultivars is the best effective practices for management of target pest. Mustard aphid can be managed by release of natural enemy. Among them effective bioagents are like, syrphid flies, *Syrphus confrater* (Weid.), *Syrphus balteatus* (Deg.), *Ischiodon scutellaris* (Fab.). *Coccinella septempunctata* is most effective insect feeder on various types of plant lice that recorded as successful bio agent of *L. erysimi*. Sprinkler irrigation helpful to wash aphid colony those attached to the apical shoot of plant and reduce aphid population by mixing them in soil. Irrigation for 2–3 times is found effective in aphid management and is economically sound. Several sustainable approaches are discussed in this article with the help of researchers' results regarding management of aphid in mustard crop.

2. Host plant resistance as effective phenomenon for controlling aphid

Crops infested by aphids are those having good sap content [3]. Consecutive selection of a plant, aphid required to adjust with it to obtain benefit from target crops. Pest consumes liquid content as its feeding material from phloem of plant via inserting stylets [4]. Plants external arrangement as well as manufactured complex substances of plants perform key role for safety of plant against aphid. External structure like, waxy content on leaf, hardness of fingernail skin, availability of spines and trichome affect aphid for selection of target portion of plant [5]. Further, leaves having alternative metabolites, healthful condition of fluid content of plant portion act as target host by plant lice [6]. Phytophagous crucifixion as well as essentiality of plants are altered with changeable climatic condition that at last ramification for their communications. [7], Increase temperature, carbon dioxide, moisture stress, environmental pollutant generally SO_2, NO as well as NO_2 enormously alter population of aphid to select its suitable target host [8]. Correspondingly, be concerned with development of aphid and their collaboration with other biotic additionally decided link with aphid and target host plant [9].

3. Nourishing mechanism of aphid on target host

Aphid changes their size by moulting process in nymphal form body that depend up on the nourishment gain from target host. Inside complexity of all harmful arthropods of mustard, aphid has the ability to bear carotenoid shade from normally in selected hosts [10]. Plant lice species does not impel toward other plant canopy as their host plant. On their selected target they attacked on generally all tender parts of plant, like vegetative, floweral part, branches and pod. Plant cell sap is suck by modified piercing and sucking type mouthparts of aphids, mouth parts of aphid are modified as needle like structure stylets combination that slices target tissue of plant to insert in phloem site and concurrently stylet penetrate in to the phloem. Aphid form two particular types of spit, protein as well as jellifying thick saliva around the stylet helpful to create an intercellular course in phloem for the purpose of penetrating stylets [11], next sorts of saliva discharge occurred to takeoff filter through stylet into the vascular structure of target host. Aphid release sugar rich material recognisable as honeydew that enhances the improvement of dirty form in the monetary patches of plants and curtail the nature of item [12]. Yet, honeydew sweet in nature attract ants for spare them from normal foes of aphid. Continuation ways of aphid about 20–40 days; its higher increase rate acts as its life assurance for maintain their population in crop ecosystem by providing protection from natural enemies.

4. Reproduction pattern of aphid

Aphid shows both sexual and asexual type of reproduction capability along with comparatively simple reproductive adjustment. On the basis of availability of host plant aphid expresses either autoecious (No change in host, monoecious) or heteroecious type of life history. Mainly aphid completes monoecious life cycle, by spending entire life on single host plant [13] but on the other hand, only 10% aphid is noted as heteroecious by completing their single life cycle on different hosts [14]. On the basis of environmental situation, aphid is capable to produce of nymphs or eggs at different time of year, it may be holocyclic means completing life cycle changing between parthenogenesis or sexual reproduction or anholocyclic means incomplete life cycle expressing only parthenogenesis but no sexual reproduction pattern life cycle followed by aphid [15]. In favourable condition aphids promote both type of life cycle. In holocyclic life cycle at low temperature eggs on primary host hatched in spring, developed in to winged mother (fundatrices), which quickly convert parthenogenesis or viviparous type of reproduction promoting wingless female population shortly. With increase of temperature wingless female gave birth of new apterous generation of aphid. In cold condition apterous aphid promoted into alate form, a few of which were males participated in sexual reproduction by mating with female and returned on primary for oviposition [16]. At the beginning of spring season hatching of these eggs occurred for recycling of life (**Figure 2**). Males are completely absent only asexual reproduction is recorded in anholocyclic life cycle. Viviparous females gives birth only female aphid parthenogenetically throughout the year (**Figure 2**). Mustard aphids are located mostly in various geographical locations, where overwintering oviposition process almost completely absent, it shows parthenogenetic type reproduction by entire year [17].

The adult females deposited eggs on tender leaves and shoot and go through an advancement of hatching. Such growth and development of plant lice with no preparation produce their little girl aphid. This structure develops via parthenogenesis type reproduction in hilly area [18]. It has affection for selection of host plant for deposition of egg mass in hilly area. Host attributes like, genetically modification, external appearance, physiological structure, engineering, appropriation, thickness of vegetative portion and physical signs are considered by plant feeder as well as aphids for proper selection of their ovipositional place [19]. In the mid year time frame they pick woody hosts for optional or agricultural crops, including vegetable harvests of families Chenopodiaceae, Compositae. Cucurbitaceae, Cruciferae and Solanaceae [20]. Yet, in the ephemeral crops aphid deposited their eggs mass on floral parts or young branches near to floweral parts [21]. Natural as well as synthetic characters of flowers of target crops alter oviposition of aphid. Female adults find out safety as well as mechanical assist in the deposition of eggs due to them select elongated floweral parts generally. Main parts of leaf having alleco-synthetic admixture as well as lipids can beside create oviposition [22]. Crop volatilise beside supporting in the reproductive improvement help in the and release of sex pheromones

Figure 2.
Infestation of Lipaphis erysimi *on mustard crop.*

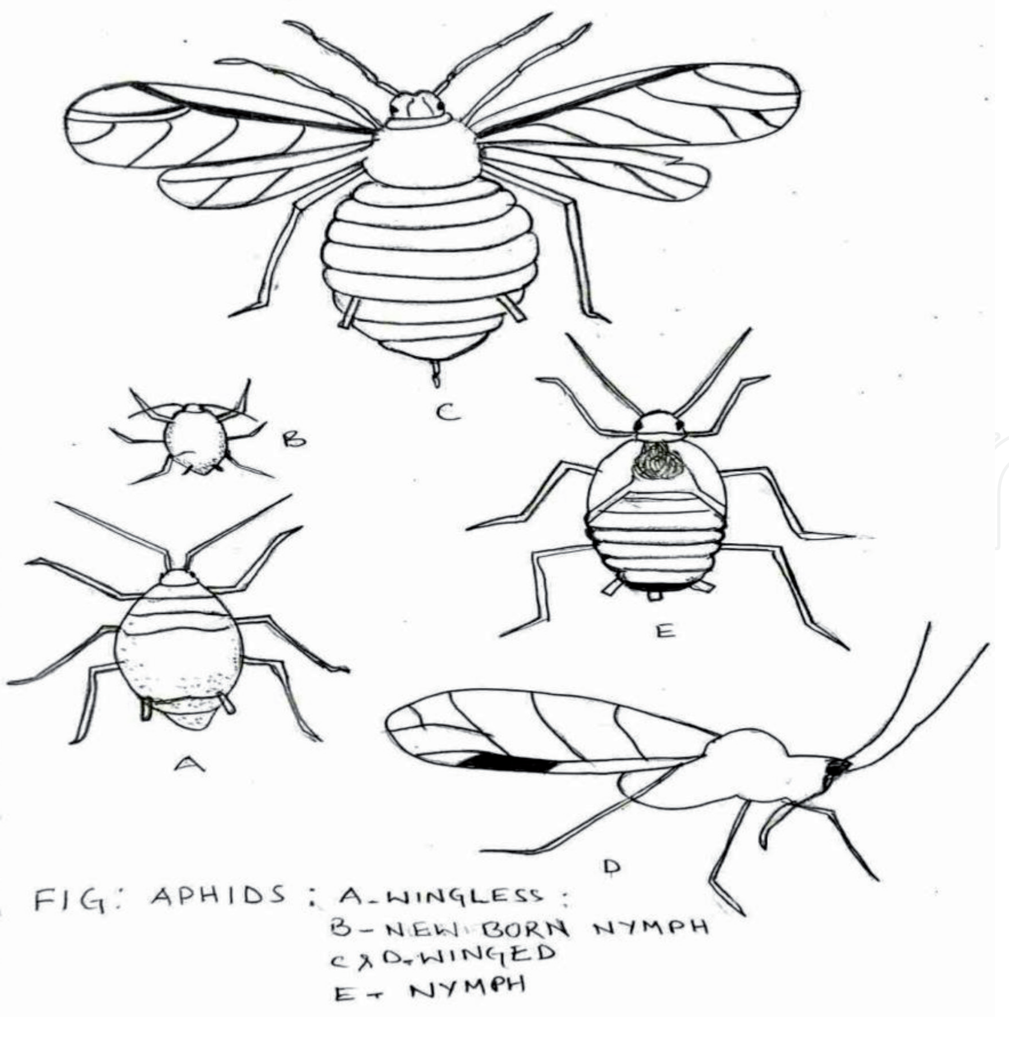

Figure 3.
Stages of mustard aphid Lipaphis erysimi.

by female aphid [23]. In plain region, *L. erysimi* reproduces entirely by viviparous parthenogenesis type reproduction from January to March month, in this particular period, the aphid completed, on an average eight generations (**Figure 3**) [24, 25].

5. Effects of temperature and drought condition on growth and multiplication of aphids

Temperature play an important role in managing wing spread, divergence, improvement as well as evolution of life stages in aphid [26]. In summer season aromatic plants provide best quality food comparison with wooded plant. Plant lice can overthrow the command forced at high temperature from dislocate themselves from that territory's host plant to other target host [27]. Increase the strength of aphid colony in crop ecosystem depends upon the optimum range of temperature. In different experiment, it was clear that occurrence and intensity of aphid were directly related on temperature as well as warm moist cloudy weather on mustard [28]. There are several acceptances that water compression approach in the recurrence of some phytophagous arthropods [29]. Aphid depends on the with balanced water pressure on plants [30]. Thus, aphid tries to move another place from their disturbed place and starts feeding on host crops where development of population easily takes placed with reduction of yield.

5.1 Factors influencing the selection and modification of target crops by aphid

Plant lice are one of the valuable agricultural destructive arthropods in crop production related with 4500 species globally. Its short life cycle completed within month, with high fecundity facilitates them to continue their destruction on crops by mass multiplication and maintaince population in the field. It acts as vector of transmitting viral diseases. Application of chemical to manage target pest population within field crops has harmful issues in as creating environmental pollution and health hazard. Regular use of synthetic molecules creates resistance in target pest as well as changes status of small population of pest in to major problem. Eco-friendly pest management practices can provide useful way for reduction of aphid population from field crop. Proper handling of crop ecosystem segment supplies excellent choice to avoid harmful effect of pesticide application. Reciprocal action of plant lice with their host plant is a basic principles for protect environment from chemical pollutant. Target crop of pests that provide shelter as well as nutritive food, aphids are phytophagous in nature dependent on various agricultural crops to complete life cycle [3]. After finding suitable host plant, aphid accommodate with it to take required nutrient from plant. They ingest liquid content as food material from phloem region of host by inserting their stylet [4]. External arrangement as well as synthetic molecule on crops is the first part of defence of plant to counter the attack of aphid such as waxy coating on upper part of leaf, hard integument, availability of ridges and trichome alter plant lice to search target crops [5]. Nutritional status and water availability within cell sap and secondary metabolites interfere in searching suitable target crops by aphid [6]. Phytophagous pest activity as well as attributes of host is affected by the modification of climatic condition that ultimately disturbs their interactions. [7], Exalted temperature, CO_2, moisture stress as well as ecosystem pollutants like SO_2, NO and NO_2 show significant impact on aphid multiplication and finding their target host crops [8]. In further, nature of damage as well as birth rate of plant lice and its intercommunication with another living organism are helpful to decide the relation among them [9]. Simple correlation with meteorological parameters revealed that among the abiotic factors (Temperature, relative humidity and rainfall), temperature had the biggest impact in enhancement as well as maintenance of aphid populace. The appearance of *Coccinella* spp. and the larvae of *Syrphid flies* are positively correlated with temperature, while there was negative correlation with the occurrence of mustard aphid *Lipaphis erysimi*. There is positive correlation between the population of aphid and relative humidity [24].

5.2 Comparable study on life table of *L.erysimi* on alternate host

Canola acts as important cash crop in Iran. *L. erysimi* is key pests of cruciferous crops globally having 10–90% damaging capability relaying on the harshness of attack on target host [31, 32]. Aphid is capable to damage on leaf, flower and fruits of canola [33]. Regarding management of aphid application of chemical pesticides causes a lot of adverse effects including toxic effects on natural enemies, outbreak of secondary pest, contamination of food web and residues creating problem on the aspect of health hazard of living organism in ecosystem [1]. To find out substitute chemical in pest management, use of bioagents is an effective tool [34]. Work on Life stages makes it easy to consider the population dynamics of insects and provide information about reproduction, survivality and development [35–38]. Lot of research work studies have appraised the effect of various *Brassica* germplasm on demographic limitation of *Plutella xylostella* (L.) [36, 39–41], *Chromatomya horticola* Goureau [42], *Myzus persicae* [42], *Thrips tabaci* [43], *Brevicoryne brassicae* L. [44, 45]. Additionally, response of several canola germplasm on various life stages of *L. erysimi* were already studied [32, 46]. Including the multiplication factors of aphid and its natural enemies on canola host at several nitrogen fertiliser treatments [34].

5.3 Function of effector protein in spreading of aphid

It is considered that available protein in aphid saliva acts as effector proteins with specific disparate function that combine to stop immune process of the target crop formation of effective colony, new approach of bioinformatics and proteomics instrument applied for identification scant strength of effectors in aphid [47–49]. Few of them effectors express excepted work like as cell wall degradation with enzyme (Amylases, pectinases, glucanases) or detoxification (peroxidases, phenol oxidases, oxidoreductase) but generally this effector was recorded as dissimilarity to protein with known work [48].

5.4 Communication through signal response in host following aphid infestation

Endogenous signalling molecule of host crop performs a significant role in the management of protective response against attack of phytophagous. Communications between the plant hormones like as gibberellic acid (GA), jasmonic acid (JA), abscisic acid (ABA), salicylic acid (SA), hydrogen peroxide (H_20_2) and nitric oxide(NO) creates a complex interrelated structure where all component influence each other by both synergistic and inhibitory communication proceeded to a protective mechanism [4]. Aphid like as *Brevicoryne brassicae, Myzus persicae* has been reported to defeat host crop by introducing resistance via manipulating of cross communication in between signalling molecules through promoting of SA- dependent pathway as well as concurrently down promoting JA-dependent pathway [50].

6. Biogical aspect as well as sustainable potential of three effective bio control agents against *L. erysimi*

Management of aphid's natural enemies such as, Ladybird beetle, *Coccinella septumpunctata* (Linnaeus), Syrphid flies, *Episyrphus viridaureus* (Wiedemann), *Betasyrphus isaaci* (Bhatia) perform significant role in mid altitude hills of Meghalaya. Basic speciality of natural enemies and functional status against target pest is very much essential to utilise them judiciously. Consequently, the biological aspect regarding consuming strength of *C. septempunctata* and syrphid flies were studied in lab condition, to get their effectiveness, strength as well as more benefits in reduction of aphid population [51–54]. *Lipaphis erysimi* (Kalt.) was found to be parasitized by ten hymenopterous parasites, belonging to two families, five genera. Out of these parasities *Diaeretus rapae* and *Aphidius spp*. play significant role in reducing aphid population. [55] *M. anisopliae* and *B. bassiana* were the most effective with less toxicity against Ladybird beetle and syrphid fly by continuously increasing population after application [56].

6.1 *Coccinella septempunctata*

Female adult deposited yellow coloured eggs in group near about 26–45. Hatching duration 3.5 ± 0.5 days to be recorded, growth and size of the larva enhanced with each successive ecdysis. Total grub duration was recorded 26 ± 3 days.. Grey to black in colour with external orange pupa was observed of *C. septempunctata.* The size of the adult and pupa approximated the same (**Figure 4**). The pupal duration was recorded 7.5 ± 1.5 days, longevity of female adult was l31.5 ± 1.5 days as well as fecundity was 357.45 ± 22.41 eggs [57, 58]. Adult beetle on an average consumed 95 aphids per day [59] adult consumed 339 aphids and larva 540 aphids (**Table 1**) [61].

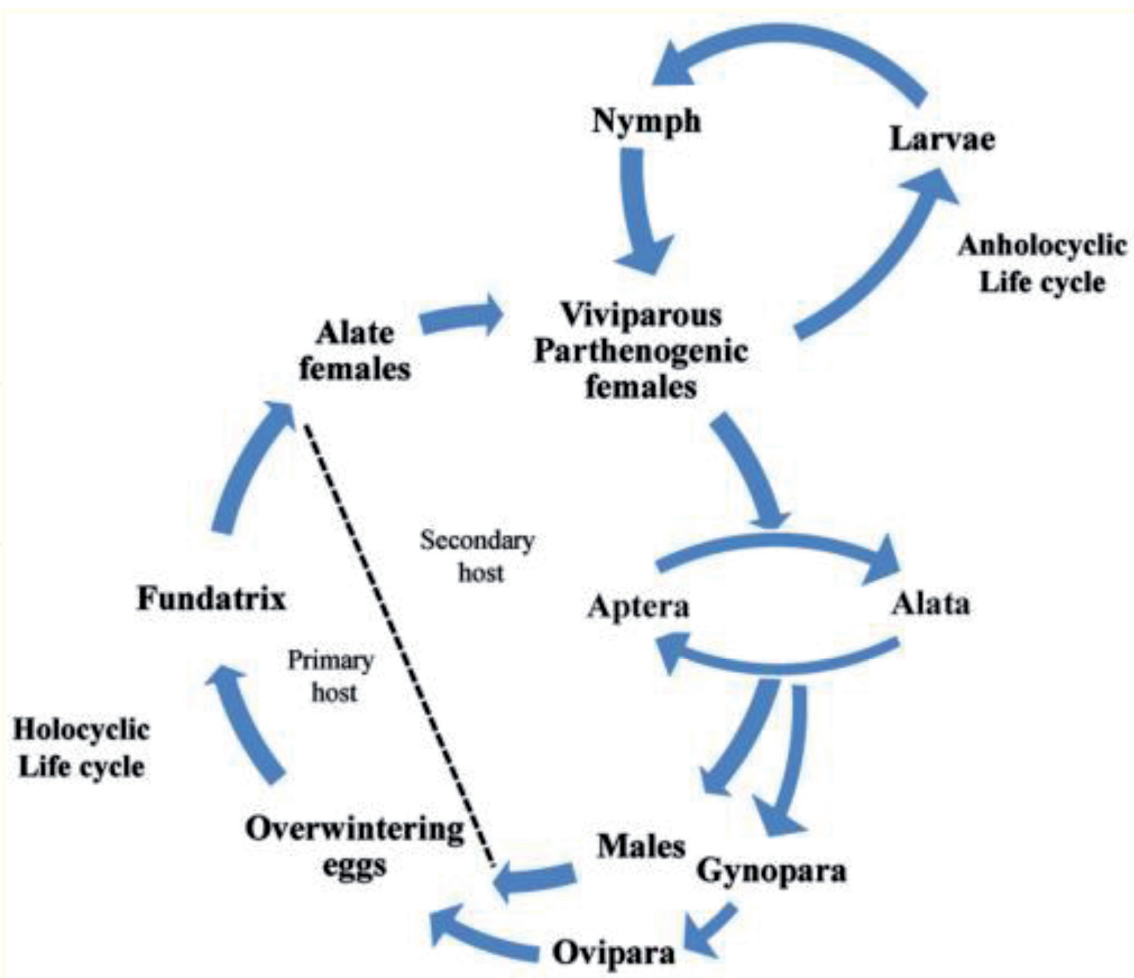

Figure 4.
Life cycle modification in aphid.

Parameter	Predators		
	Coccinella septempunctata	***Episyrphus viridaureus***	***Betasyrphus isaaci***
Incubation period	3.5 ± 0.5 days	03 ± 0.5 days	3 ± 1 days
Larval period	26 ± 3 days	22 ± 1.5 days	21 ± 1.5 days
First instar	3.5 ± 0.5 days	12.9 ± 1.0 days	13 ± 0.5 days
Second instar	7.5 ± 1.5 days	4.1 ± 0.5 days	3.90 ± 1.0 days
Third instar	6.5 ± 0.5 days	5.0 ± 1.0 days	4.0 ± 0.5 days
Fourth instar	8.5 ± 1.0 days	—	—
Pupal period	7.5 ± 1.5 days	7 ± 1 days	8 ± 1 days
Adult longevity	31.5 ± 1.5 days	14 ± 1.5 days	13 ± 1 days
Life cycle	68.5 ± 6.5 days	47 ± 2 days	41 ± 2 days
Fecundity	357.45 ± 22.41. No/female	45.0 ± 16.8. No/female	31.2 ± 13.6. No/female

Source: [60].

Table 1.
Biological attributes of three predators of mustard aphids under laboratory conditions.

6.2 *Episyrphus viridaureus*

Near or within colony of aphid single eggs deposition occurred by *E. Viridaureus.* White colour and oblong in shape eggs hatching was recorded up to 3 ± 0.5 days. Immature stage completed three larval instars. Intrusting, apodus larvae of *E. viridaureus* had a permeable body, inter*nal* organs clearly visible. Life span of larvae was recorded to be 22 ± 1.5 days. Creamy as well as pear frame, tapered at the one side of pupae had 7 ± 1 day duration. Longevity of adult female was a 14 ± 1.5 day with fecundity was 45.0 ± 16.8 eggs. Total life history was completed in 47 to 49 days. f *E. balteatus* was recorded to take 21.2 days to completes its life cycle having larval duration of 7.6 days (**Table 1**) [62].

6.3 *Betasyrphus isaaci*

Greyish in colour as well as oblong shaped eggs deposited by adult female had incubation duration 3 ± 1 days. Larval period completed within 21 ± 1.5 days having three larval instars. 8 ± 1 days were recorded as pupal period. Longevity of adult female was 13 ± 1 days as well as laid 31.2 ± 13.6 eggs (**Table 1**).

6.4 Consumption capability of predators on aphid

The study on these predators, feeding capability on plant lice noticed that last grub instar devoured highest aphids than earlier instar grub and enhance each consecutive instars. Such capability of natural enemies' grub of *C. septumpunctata* was observed higher than both the species of syrphid flies. Individual adults of lady bird beetle feed on an average of 81.55 ± 15.34 aphids per daily and ultimately feed on 2691.00 ± 533 aphids during mature stage. Both grub and adult stages of it are predatory in nature and therefore it was recorded most superior predator of mustard aphid. One adult feed near about 4312 ± 537.74 aphids in a lifespan; which is much more than *E. viridaureus* (416.67 ± 6.76 aphids) and white fly (338 ± 7.89 aphids). Maximum feeding occurred during final instar of grub which could be

Stages	Daily consumption of aphids per day (Mean ± SE)			Consumption per life stage (Mean ± SE)		
	Coccinella septempunctata	***Episyrphus viridaureus***	***Betasyrphus isaaci***	***Coccinella septempunctata***	***Episyrphus viridaureus***	***Betasyrphus isaaci***
First instar	20.42 ± 00.42	07.30 ± 0.08	06.51 ± 0.17	081.67 ± 0.33	095.00 ± 1.51	084.67 ± 1.30
Second instar	35.00 ± 00.99	23.58 ± 0.22	23.75 ± 0.29	315.00 ± 1.34	094.00 ± 4.30	095.00 ± 4.80
Third instar	65.48 ± 01.27	45.53 ± 1.09	39.58 ± 1.46	458.33 ± 1.29	227.67 ± 0.95	158.33 ± 1.79
Fourth instar	85.11 ± 01.39	—	—	766.00 ± 1.78	—	—
Adult	81.55 ± 15.34	Free living	Free living	2691.00 ± 533	Free living	Free living
Total cons umption				4312 ± 537.74	416.67 ± 6.76	338.00 ± 7.89

Source: [60].

Table 2.
Feeding potential of three major predators of Lipaphis erysimi.

associated with modification of mouth structure as well as excellent metabolism than early instars. This result provided support to several outcomes on feeding capability of different syrphid and *coccinellids* [1, 63–65]. The first to fourth instar of grub of lady bird beetle feed on 21.43, 46.90, 72.61, and 102.60 aphids daily, respectively [1]. The feeding capability on prey of *Episyrphus spp*. enhanced slowly with the growth of grub [64]. Observation regarding the feeding potential of white fly is not available in the existing literature, however, reported that the first, second and third instar of another closely related syrphid, *B. serarius* feeds on 11.5, 44.75 and 232.5 aphids daily (**Table 2**) [65].

7. Occurrence and management of mustard aphid through cultural practices

Thirty-eight insect pest incidences are recorded on mustard crop in India. In the country among them aphid acts as key pest in mustard growing region. Nymphs and adults both stages of aphid damaged crop by sucking liquid food material from the leaves, flowers as well as siliquae making the qualitative and quantitive loss in yield. Aphid reduced 35.4 to 96% yield loss, 30.9% weight loss and 2.75 per cent oil loss in mustard [66–69].

7.1 Date of sowing

The occurrences of *L. erysimi* as well as its population build up were recorded at full flowering stage and full pod setting stage of the crops. The yield of various varieties was recorded at harvest. Rapeseed-mustard varieties sown during first and third week of October, minimum level of aphid infestation, while those sown in first and third week of November, were infested heavily, Among the varieties, the gobhi sarson (HPN-1) was highly susceptible to the aphid attack, while *B. carinata* (HPC-1) was least infested as compared to other varieties. Varieties sown early provided greater yield, while Varuna and HPC-1 gave the higher yield than the rest, irrespective of sowing date [70]. The *L. erysimi* population was minimum in crops sown on 10thOctober and maximum in crops sown on 24thNovember where average aphid population was 40.70 aphids/10 cm twigs. Indian mustard sown on 10thOctober successfully evaded the infestation of the 2 insect pests during the study [71]. Significantly least aphid population of 7.3 and 7.4 aphids/10 cm apical shoot on the seasonal total emergence to maturity was recorded on early sowing. Variety Rohini (15th October) provided the effective combination having less aphid population but higher yield, 58.6 and 60.4 aphids/10 cm apical shoot and seed yield, 1670.7 and 1915.1 kg/ha [2].

7.2 Utilisation of aphid resistant variety

Application of resistance cultivar acts as eco-friendly way to control aphid infestation on Brassica crops. For development of resistant variety utilisation of conventional breeding techniques required lot of time and repetition due to deficiency of resistant component in cultivated as well as wild relative of Brassica. In recent screening of two wild type Brassica varieties (*B. fruticulosa* and *B. montana*) followed by breeding chance of *B. juncea* showing heritable introgession against resistance of aphid in lab condition [72]. Based on pooled mean of aphid infestation index (0–5 rating scale), genotypes were classified to different grade of resistance. Out of 65 genotypes, six genotypes viz., NDR-05-1, RW-2-2, ONK-1, NRCKR-299, Kiran and T-27 were categorised as highly resistant, 16 genotypes were found as resistant, 21 genotypes were found moderately resistant, 13 genotypes were graded as susceptible and remaining nine genotypes were highly susceptible. Three *Brassica* genotypes (NRCKR-299, Kiran and T-27) were found consistently as highly resistant at both full flower and pod stages [73, 74]. On the basis of aphid infestation index at the time of flowering as well as siliqua development, it was observed that varieties Varuna and Vaibhav were susceptible to aphid infestation. Uravasi, Maya, Vardan, Ashirvad and Pitambari were noted as fairly resistant to aphid while Rohini showed resistance to aphid incidence [75]. Avoidable mustard production loss due to L. *erysimi* were checked in four cultivar of Karan rai, Ethiopian mustard as comparative with Indian mustard Varuna [76].

7.3 Balanced application of fertilisers

Combined utilisation of biofertilizers, growth retardant and compost can therefore be employed for regulating crop metabolism and physiological responses resulting in enhanced crop growth and protection against pathogens and pest [77].

7.4 Role of yellow sticky trap in aphid management

Performance of yellow sticky trap and imidacloprid 17.8% SL was assessed on farmer's field through front line demonstrations. The per cent increase in the yield under demonstration technology was 18.52% and 26.99% over the farmer's practices [78]. Monitoring of alate aphid initial average population ranged from 0.93 to 19.42 aphids per trap and attained to peak at interval relay upon the climatic factors from 9th to 12th standard week [79]. The initial average population ranged from 0.2 to 0.6 aphids per trap and came to peak alternately relaying upon the climatic factors during 7th to 10th standard week [80].

8. Application of entomopathogenic fungus in management of aphid

Lot of commercial fungal biopesticides with several brand names as well as formulations are available as agro-product globally [81]. The perverted entomopathogenic fungi *Beauveria bassiana* (Balsamo) *Vuillemin* and *Metarhizium anisopliae* (Metschnikoff) Sorokin are bioagents of a wide range of soft bodied insects including aphids, mealy bugs and arachnids; both fungi have a cosmopolitan distribution [82, 83]. *Lecanicillium (Verticillium) lecanii* (Zimm.) Zare & Gams has been used against greenhouse whitefly, thrips and aphids [84–86]. Similarly, *Paecilomyces fumosoroseus*, *P. farinosus and P. lilacinus* have been reported as entomopathogenic on a variety of insect pests [87, 88]. Very little information is available on the use of indigenous entomopathogenic fungi for the control of insect pests in Pakistan [84, 85]. A local strain *of M. anisopliae* was applied against cabbage aphid *Brevicoryne brassicae* L. This strain has also been screened for its compatibility with insecticides. Similarly, two local strains *of M. anisopliae* were used against *Coptotermes heimi* Wasmann [89]. The present report describes the efficacy of exotic and indigenous strains of *M. anisopliae, Paecilomyces lilacinus, Lecanicillium lecanii* and *B. bassiana* against the mustard aphid. Among entomopathogenic biopesticides *M. anisopliae* (83.23%) was found to be the most effective against mustard aphid followed by *B. bassiana* (78.33%) and *B. thuringiensis* (73%). Bio-pesticides can be used as a potential candidate for integrated pest management against mustard aphid after field efficacy [90]. Biological control of crop pests and diseases has been found to play significant role in reducing the over reliance on chemical pesticides.

9. Botanical pesticides

The crude aqueous extracts from *Ageratum conyzoides* (L.), *Parthenium hysterophorus* (L.), *Lantana camera* (L.), *Solanum nigrum* (L.), *Cannabis sativa* (L.), *Calotropis gigantean* (L.), *Livistona chinensis* (Jacq.), *Cassia angustifolia* (Mill.) were checked for its insecticidal as well as repellent activity against *M. persicae* (Sulzer) and *Brevicoryne brassicae* (Linnaeus). Repellent activity was inversely related to concentration of plant extract [91]. The antioxidant activities of different fraction of the methanolic extracts were indicated in the range of 69.08–84.89%. Thirty-four leaf extracts as well as *Azadirachta indica* were checked against healthy aphids kept in petri plates. It was observed that all the treatments show insecticidal properties versus aphid but the extract from *Chrysanthemum*, *Calotropis procera* noted result at par with *A. indica.* The other plant extracts *Zingiber offcinale, Ageratum conyzoides*, *Lantana camera*, Pinus roxburghii, *Allium sativum*, *Ricinus communis*, *Cymbopogon citrates* and *Hevea brasiliensis* yielded excellent outcomes [92] showing in **Table 3**.

S. No.	Local Name	Scientific Name	Parts used	Per cent morality of aphid
1	Adrak	*Zingiber officinale*	Leaves	22.20
2	Bael	*Aegel marmelos*	Leaves	14.43
3	Neela phulnu	*Ageratum conyzoides*	Leaves	29.96
4	Panch phuli	*Lantana camera*	Leaves	22.16
5	Banna	*Vitex negundo*	Leaves	13.30
6	Curry leaf	*Murraya koengii*	Leaves	6.66
7	Bougainvillea	*Bougainvillea glabra*	Leaves	9.86
8	Mint	*Mentha spicata*	Leaves	8.86
9	Bhang	*Cannabis sativa*	Leaves	22.20
10	Neem	*Azadirachta indica*	Leaves	35.43
11	Simal	*Bombax ceiba*	Leaves	15.50
12	Camphor	*Cinnamomum camphora*	Leaves	6.63
13	Morphanki	*Thuja orientalis*	Leaves	6.63
14	Datura	*Datura stramonium*	Leaves	4.40
15	Congress grass	*Parthenium hysterophorus*	Leaves	9.96
16	Pines	*Pinus roxburghii*	Leaves	26.63
17	Bamboos	*Bambusa arundinacea*	Leaves	4.40
18	Darek	*Melia azedarach*	Leaves	9.96
19	Jungle chulai	*Amaranthus spinosus*	Leaves	1.22
20	Amla	*Pylllanthus emblica*	Leaves	8.86
21	Harrar	*Terminalia chebula*	Leaves	18.86
22	Ak	*Calotropis procera*	Leaves	32.20
23	Gul-e—Daudi	*Chrysanthum coronarium*	Leaves	41.06
24	African Marigold	*Tagetus erecta*	Leaves	17.76
25	Burweed	*Xanthium strumarium*	Leaves	6.63
26	Kinnow	*Citrus sinensis*	Leaves	19.96
27	Garlic	*Allium sativum*	Leaves	25.53
28	Soybean	*Glycine max*	Leaves	17.73
29	Castor	*Ricinus communis*	Leaves	23.30
30	Talhi	*Delbergia sissoo*	Leaves	18.86
31	Lemon grass	*Cymbopogon citrates*	Leaves	26.63

S. No.	Local Name	Scientific Name	Parts used	Per cent morality of aphid
32	Jambolan	*Syzygium cumini*	Leaves	16.66
33	Rubber plant	*Hevea brasiliensis*	Leaves	22.20
	CD (P = 0.05)			5.8

Source: Srivastava & Guleria, (2003).

Table 3.
Evaluation of various plant-extracts against mustard aphid, Lipaphis erysimi.

10. Conclusion

In this chapter it can be concluded that aphid acts as dominant among all pest of mustard crop having 10–90% damaging capability with a significant reduction of yield. To avoid indiscriminate application of synthetic pesticides those show harmful effect on beneficial organism and application of eco-friendly management practices should be employed. However we will require extending of dynamics communication between host plant resistance as well as biological control with target pest in relation to changing climatic condition.

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