Soil fertility management and its impact on mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Hemiptera: Aphididae)

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Soil fertility management and its impact on mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Hemiptera: Aphididae)

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Abstract: Maize-mustard cropping sequence is the most adopted cropping pattern in the rainfed belt of Jammu region, Jammu & Kashmir, India. Mustard is attacked by aphids, flea beetles, saw flies and painted bugs, among which aphids are of great economic importance. An experiment was conducted to assess the impact of various organic and inorganic fertilizers / pesticides on mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Hemiptera: Aphididae). During 2009–2010 and 2010–2011, mustard was sown applying Farm Yard Manure, Neem cake, *Adhatoda vasica* twigs, Di Ammonium Phosphate and Muriate of Potash (MOP) at different rates and their impact on mustard aphid incidence was studied. The lowest aphid population was noticed in MOP at 80 kg/ha. This was followed by MOP at 40 kg/ha or Neem cake at 5 quintals/ha. The aphid incidence was highest in plots treated with higher dose of DAP at 120 kg/ha (117.97 aphids per ten cm twig), showing the adverse impact of application of higher dose of nitrogenous fertilizer. Application of neem cake also acted as fertilizer and recorded highest yield of 7.34 q/ha along with MOP at 80 kg/ha (7.34 q/ha). The impact of application of various organic and inorganic fertilizers on available soil nutrients, was also recorded after the completion of two year experiment during 2010–2011 (post harvest soil samples).

ABOUT THE AUTHORS

Reena Sinha (b. 1st Dec., 1975) started her professional career as Assistant Professor-cum-Junior Scientist from July, 2004 at SKUAST-Jammu and has thirteen years of experience in Research, Extension work and teaching. She is also the recipient of Junior Research Fellowship (ICAR) during MSc. (Ag) degree program and Department of Science and Technology (DST), Government of India, Young Scientist Project Award (2009–2012). She has handled two externally funded project as PI and two as Co-PI, besides several other internally funded research projects. She has delivered several expert lectures to the Department Agriculture personnel, farmers, pesticide dealers and other agriculture workers. She has published more than 25 research papers in journals of national and international repute. She has 10 book chapters, two research manuals and more than ten technical bulletins to her credit.

The author has worked on alternate methods of pest management since 1998 and the present work is also one in the line.

PUBLIC INTEREST STATEMENT

Insect pests especially mustard aphids pose a serious threat to mustard growers. They are forced to apply chemical pesticides to manage them. Looking to the harmful implications of applying chemical pesticides in the environment, ecological systems and human health, experiments were conducted to find an alternative to it. Soil application of fertilizers is known to impact insect pest incidence in fruit trees (peach, walnut) and also field crops (millets, maize, etc.). In the present study, response of organic fertilizers viz., neem cake, farm yard manure (FYM) and *Adhatoda vasica* twigs as well as inorganic fertilizers, Di-Ammonium Phosphate (DAP) and Muriate of Potash (MOP), to aphid incidence and seed yield of mustard, was recorded. Application of MOP at 80 kg/haere greatly reduced mustard aphid population and also increased the seed yield. This was followed by the neem cake applied at 5 quintals/ha. MOP or neem cake can therefore be applied as an alternate method of managing mustard aphid in a safe manner.
Subjects: Environment & Agriculture; Bioscience; Environmental Studies & Management

Keywords: maize stem borer; insect pests; organic fertilizers; inorganic fertilizers

1. Introduction

The most important management for high yielding production system is nutrition management, which also affects the response of plants to insect pests and diseases. The knowledge of nutrition management in relation to insect pests and diseases incidence forms the basis for setting up a high yield production system (Chau & Heong, 2005). The capacity of a resistant plant to resist attack of insect pests and diseases is strictly related to optimal physical, chemical and mainly biological characteristics of soils. Soils with high organic matter and active biological activity exhibit good soil fertility as well as complex food webs and beneficial organisms that prevent infection. The organically grown crops have been recorded to show more tolerance/resistance to insect attacks, while those farming practices that cause nutritional imbalances, lowers pest resistance (Magdoff & Van, 2000). Soil nutrient availability, not only affects the amount of damage that plants receive from herbivores, but also their ability to recover/withstand that damage. Soil fertility practices also impacts the physiological susceptibility of crop plants to insect pests by either affecting the resistance of individual plant to attack or by altering the plant acceptability to certain herbivores.

Numerous factors enhance the insect pest problem in field, by manipulating the environment favorable for growth, reproduction and development of insects including traditional cultural methods, unrestricted use of chemicals (insecticides) and imbalanced use of fertilizers, etc. (Karimullah, Khan, & Raqib, 1986; Matthews, 1983). Nitrogen, phosphorus and potassium are fundamental nutrients for plant growth and development which play a basic role in metabolism and energy production in plants and significantly enhance the grain yield. Leaf area duration, leaf area index (LAI), and crop photosynthetic rate reduces under nitrogen stress (Uhart & Andrade, 1995), but its excessive use besides causing wastage of resources, can also lead to pest problems by increasing the reproduction, longevity and overall fitness of definite pests. Damage to crops by insect pests amplifies with the application of fertilizers (Sétamou, Schulthess, Bosque-Pérez, & Thomas-Odjo, 1993, 1995). Increased nitrogen applications to crops influence plant-herbivore interactions and potentially increase herbivore population growth (Fallahpour, Ghorbani, Nassiri, & Hosseini, 2015). On the other hand crop growth rate reduces under nitrogen stress that leads to decrease in kernel number and grain yield (Uhart & Andrade, 1995). Millet crop grown on high rates of nitrogen survives, and following crop damages due to increased borer population is amplified as compared to low rates of nitrogen fertilizer (Tanzubil, Zakariah, & Alem, 2006). It has been observed that the application of high doses of nitrogen fertilizer notably increases the number of egg masses deposited by Asian corn borer, Ostrinia furnacalis on maize leaves, which ultimately becomes a serious threat for the production.

Mustard is inflicted by numerous insect pests at various stages of its growth, major among them are mustard aphid, flea beetle, etc. which are considered as the most damaging one. Both adults and nymphs of mustard aphids suck juice from the leaves, stem, inflorescence and growing pods resulting in curling of leaves. On severe infestation, pods fail to develop, do not produce healthy seeds and the oil content of seed reduces. There are reports where increased fertilization has increased the susceptibility of plants to mustard aphids. Therefore, aphids feeding on plants receiving higher nitrogen levels had shorter nymphal developmental time, longer adult longevity as well as greater fecundity (Fallahpour et al., 2015). Manipulations with plant nitrogen fertilization is expected to serve as pest management tool. In a study conducted in young peach at the three intermediate N levels, aphids (Myzus persici) populations increased over time (Zehnder & Hunter, 2008). Hosseini, Hosseini, Goldani, Karimi, and Madadi (2015), reported enhanced aphids (Aphid craccivora) intrinsic rate of natural increase on plants fertilized with 100% of the recommended N level. Abundance and population growth rate of aphid was also positively correlated with N fertilization levels in common globe amaranth. However, few workers have reported a decrease in herbivore population growth rates with the experimental increases in foliar nitrogen levels, suggesting that excessive nutrient levels can limit herbivore population growth rates (Zehnder & Hunter, 2009).
Potassium is taken up by crops from soils in relatively large quantities. Potassium is implicated to increase plant resistance to diseases and insect pests. It basically helps in the development of a strong and healthy root system and increases the uptake and use of N and other nutrients. Increase in aphid incidence with increasing fertilizer levels was noticed in Brown sarson and Gobhi sarson, while the Ethiopian mustard was resistant to aphids at all fertilizer levels (Choudhary, Ramesh, & Sharma, 2001).

Though researches of this kind have been done for years, most of the work is focused on impact of chemical fertilizers especially nitrogen and silicon on major pests. Nitrogen has been found to be one of the most important factors in development of herbivore populations. The application of nitrogen fertilizer in plants can normally increase herbivore feeding preference, food consumption, survival, growth, reproduction and population density in most of the cases (Zhong-Xian, Xiao-Ping, Kong-Luen, & Cui, 2007). The understanding of these interactions between soil fertility status and insect pests and disease incidence becomes the basis for design of any sustainable production system.

In rainfed belt of Jammu, the major cropping sequence followed is maize-mustard. The rainfed belt of Jammu & Kashmir stretches between longitude 74°21′ and 75°45′ E and latitude 32°22′ and 32°55′ N. Insect pests attack in mustard creates serious problem and greatly reduces yield. Application of various fertilizers, in addition to affecting grain yield, has been known to impart either resistance or susceptibility towards insect pests and diseases. *Adhatoda vasica* is native to Asia Pacific region and is also produced in Sri Lanka, Malaysia, Indonesia, and China. It is a powerful shrub growing in the lower Himalayans, up to a range of 1,000 m above sea level (between 32°17′ and 37°5′ N latitudes and 72°40′ and 80°30′ E longitudes). Its leaves contain phytochemicals such as alkaloids, tannins, saponins, phenolics and flavonoids. In traditional Indian medicine, it has been used to treat respiratory disorders like asthma for thousands of years (Caldecott, 2006; Chopra, 1982). The ancestral farmers of this rainfed belt used to apply *Adhatoda vasica* twigs as mulch in their crops. This helped save moisture, besides adding nutrients and protecting the crop from various insect pests and diseases, due to the presence of the chemical Vasicine and Vasicinone in this plant.

Keeping the above facts in view, the present investigation to see the impact of various organic and inorganic fertilizers/pesticides on mustard aphid, *Lipaphis erysimi* (Kaltenbach) incidence was conducted.

### 2. Materials and methods

Mustard cv. DGS-1 was sown in October, 2009–2010 and 2010–2011 at the Research Farm of Advanced centre for Rainfed Agriculture, Dhiansar, 32°39″ N and 74°24″ E imposing all the below mentioned treatments. The soil type of this zone is characteristic inceptisol. The rainfed soils are generally low in fertility due to poor organic matter content. The average annual rainfall here varies from 1050–1150 mm. The treatments were laid in a Randomized Block Design with three replications in a plot size of 3.0 × 4.0 m², maintaining a row distance of 30 cm and plant to plant distance of 10–12 cm.

- **T1** Farm Yard Manure (FYM) at 5 tonnes/ha
- **T2** FYM at 10 tonnes/ha
- **T3** Neem cake at 2 quintals/ha
- **T4** Neem cake at 5 quintals/ha
- **T5** *Adhatoda vasica* leaves at 15 tonnes/ha
- **T6** Di Ammonium Phosphate (DAP) at 80 kg/ha
- **T7** DAP at 120 kg/ha
- **T8** Muriate of Potash (MOP) at 40 kg/ha
- **T9** MOP at 80 kg/ha
- **T10** Control
All these treatments were applied as basal dose at the time of sowing. Well rotten Farm Yard Manure (FYM) taken from farmer was applied at the time of sowing in two treatments T₁ and T₂. Commercially available neem cake prepared after extraction of neem oil from the seed kernels, was applied in T₃ and T₄. To see the impact of application of A. vasica leaves on stem borer population, it was applied in T₅ at 15 tonnes per hectare. Higher doses of DAP and MOP was applied at the time of sowing in T₆, T₇, T₈ and T₉.

Mustard aphid incidence was recorded throughout the mustard growing season. The aphid infestation started from February, when the crop was in early flowering stage. Observations on aphid counts were recorded at every fortnight intervals, and the final data is the mean of all observations. Number of aphids (both nymphs and adults) present per top 10 cm twig was recorded. Ten such random counts were per plot, covering the whole plot area. The final seed yield per plot was also recorded, that was converted to kg/ha. The cost involved and benefits accrued were also calculated treatment-wise for all the three years (2009–2010, 2010–2011 and 2011–2012). To assess the impact of application of various organic and inorganic fertilizers on available soil nutrients, soil samples were analyzed initially before sowing in October, 2009 and after the completion of two year experiment in April, 2011 (post harvest soil samples). Organic Carbon content was estimated using the method of Walkley and Black (1934). Available soil nitrogen was analyzed by alkaline Potassium Permanganate method of Subbiah and Asija (1956), available P₂O₅ was determined by the method of Olsen, Cole, Wantanabe, and Dean (1954), available K₂O was estimated by neutral normal ammonium acetate (Jackson, 1973). Initial available Nₙ, P₂O₅ and K₂O is 172, 15.1 and 108 kg/ha respectively, while the soil pH was 6.58.

Mustard was sown imposing all the same treatments, following the same design with three replications in October, 2010 also, to confirm the findings of earlier experiment conducted in 2009–2010. Mustard aphid incidence and final seed yield was recorded as earlier. Percent increase or decrease in aphid population (Abbott’s formula) and seed yield in response to the application of these organic and inorganic fertilizers was also calculated using the following formulae.

\[
\text{Percent reduction} = \frac{\text{Aphid population in Control} - \text{Aphid population in treatment}}{\text{Aphid Population in control}}
\]

\[
\text{Percent increase in yield} = \frac{\text{Seed yield in treatment} - \text{Seed yield in control}}{\text{Seed yield in control}}
\]

The two best treatments were combined and assessed for their efficacy during 2011–12. For all the three years, the cost benefit ratio was also calculated.

Data for all the three years were analyzed separately. All the data were subjected to analysis of variance (ANOVA) in a Randomized Block Design. The yield data, nitrogen, phosphorus, potash and organic carbon, were analyzed without transformations. The one-way analysis of variance (ANOVA) in Statistical Package for the Social Sciences (SPSS version 14.0) and SAS version 9.3 software was used to determine whether there are any statistically significant differences between the means of two treatments. Treatment means were separated using Duncan’s Multiple Range Test.

3. Results
Experiments were conducted on mustard, imposing the treatments as mentioned in the material and methods, during 2009–2010 and 2010–2011. Mustard aphid incidence was the least in MOP at 80 kg/ha (38.00 aphids per ten cm twig) followed by MOP at 40 kg/ha (57.07 aphids), proving the effect of MOP in imparting resistance to the plants (Table 1). The incidence was highest in plots treated with higher dose of DAP at 120 kg/ha (117.97 aphids), showing the adverse impact of application of higher dose of nitrogenous fertilizer. Application of neem cake at 5 tonnes/ha, Adhatoda vasica leaves at 15 tonnes/ha also significantly reduced the aphid incidence (57.00 and 62.87 aphids respectively in these two treatments). Application of neem cake also acted as fertilizer boost up and
recorded highest yield of 734.72 kg/ha along with MOP at 80 kg/ha (734.72 kg/ha). This was followed by the application of *A. vasica* leaves at 15 tonnes/ha (686.11 kg/ha seed yield) and neem cake at 2 quintals/ha (673.61 kg/ha). Mean number of aphids and seed yield obtained in various treatments is depicted in Figure 1.

During the next year 2010–2011, when the same experiment was repeated, for confirmation of results, application of MOP at 80 kg/ha, recorded least number of aphids (51.90) per ten cm twig of mustard (Table 2). Application of MOP at 40 kg/ha (64.27) and neem cake @ 5 quintals/ha (69.73) also recorded comparable number of aphids per ten cm twig. Here again, DAP at 120 kg/ha applied plots showed the highest aphid incidence (138.00 aphids per ten cm twig). Seed yield was however, highest in neem cake at 5 quintals/ha (844.44 kg/ha) and MOP at 40 kg/ha (844.44 kg/ha) and MOP at 80 kg/ha (841.66 kg/ha). Application of higher doses of nitrogenous fertilizers viz., DAP at 80 kg/ha and 120 kg/ha, did not result in increased seed yield, as it enhanced the vegetative growth of the plant and also increased the aphid population. Mean number of aphids and seed yield obtained in response to various fertilizers application is depicted in Figure 2.

Percent reduction or increase in aphid population and seed yield in treated plots over control plots was also calculated for both the years (Table 3). The average of two years showed maximum percent reduction in aphid population in MOP at 80 kg/ha (56.89%), followed by MOP at 40 kg/ha (41.11%) as evident from Table 3. However, the percent increase or decrease in seed yield was highest in MOP at 80 kg/ha (19.65%) and Neem cake at 5 q/ha (19.65%) followed by MOP at 40 kg/ha (19.00%).

### Table 1. Mustard aphid incidence as affected by fertilizer application during 2009–10

| Treatments | Mean No. of aphids/10 cm twig | Percent reduction in aphid population over control | Seed yield (q/ha) | Percent increase in seed yield over control |
|------------|-------------------------------|-----------------------------------------------|------------------|-------------------------------------------|
| T1         | 92.53±2.810                   | −1.76                                         | 6.25±0.070       | 1.35                                      |
| T2         | 106.00±4.503                  | −16.57                                        | 6.31±0.735       | 2.25                                      |
| T3         | 70.60±5.529                   | 22.36                                         | 6.74±0.141       | 9.23                                      |
| T4         | 57.00±4.104                   | 37.31                                         | 7.35±0.123       | 19.14                                     |
| T5         | 62.87±2.890                   | 30.86                                         | 6.86±0.100       | 11.26                                     |
| T6         | 92.27±2.228                   | −1.47                                         | 5.92±0.040       | −4.05                                     |
| T7         | 117.97±5.977                  | −29.74                                        | 6.03±0.100       | −2.25                                     |
| T8         | 38.00±3.972                   | 58.21                                         | 7.29±0.120       | 18.24                                     |
| T9         | 57.07±2.095                   | 37.24                                         | 7.35±0.077       | 19.14                                     |
| T10        | 90.93±3.069                   | −                             | 6.17±0.482       | −                                         |

![Figure 1. Mean number of aphids and seed yield obtained in various treatments during 2009–2010.](image.png)
Available N₂ was significantly affected by different treatments; the highest being in Neem Cake at 5 tonnes/ha (192.77 kg/ha); FYM at 10 tonnes/ha (190.68 kg/ha) and Adhathoda vasica twigs (184.39 kg/ha) (Table 4). While, highest available Phosphorus was in FYM at 10 tonnes/ha (15.76);

Table 2. Mustard aphid incidence as affected by fertilizer application during 2010–11

| Treatments | Mean No. of aphids/10 cm twig | Percent reduction in aphid population over control | Seed yield (q/ha) | Percent increase in seed yield over control |
|------------|-------------------------------|-----------------------------------------------|-------------------|---------------------------------------------|
| T₁         | 114.30± 3.932                | 2.17                                          | 7.14± 0.073       | 1.58                                        |
| T₂         | 119.07± 8.054                | −1.92                                         | 7.47± 0.074       | 6.32                                        |
| T₃         | 96.00± 6.923                 | 17.83                                         | 7.80± 0.056       | 11.07                                       |
| T₄         | 69.73± 3.862                 | 40.31                                         | 8.44± 0.169       | 20.16                                       |
| T₅         | 80.57± 3.961                 | 31.04                                         | 7.90± 0.050       | 12.45                                       |
| T₆         | 116.00± 7.425                | 0.71                                          | 6.83± 0.127       | −2.77                                       |
| T₇         | 138.00± 7.130                | −18.12                                        | 6.86± 0.169       | −2.37                                       |
| T₈         | 51.90± 2.748                 | 55.58                                         | 8.42± 0.209       | 19.76                                       |
| T₉         | 64.27± 3.568                 | 44.99                                         | 8.44± 0.195       | 20.16                                       |
| T₁₀        | 116.83± 8.574                | −                                             | 7.03± 0.055       | −                                           |

Figure 2. Mean number of aphids and seed yield obtained in various treatments during 2010–2011.

Table 3. Mean percent reduction or increase in aphid population and seed yield over two years 2009–10 and 2010–11

| Treatments | Percent reduction or increase in aphid population over control | Percent increase or decrease in seed yield over control |
|------------|---------------------------------------------------------------|--------------------------------------------------------|
| T₁         | 0.20                                                          | 1.47                                                   |
| T₂         | −9.25                                                         | 4.29                                                   |
| T₃         | 20.09                                                         | 10.15                                                  |
| T₄         | 38.81                                                         | 19.65                                                  |
| T₅         | 30.95                                                         | 11.86                                                  |
| T₆         | −0.38                                                         | −3.41                                                  |
| T₇         | −23.93                                                        | −2.31                                                  |
| T₈         | 56.89                                                         | 19.00                                                  |
| T₉         | 41.11                                                         | 19.65                                                  |
| T₁₀        | −                                                             | −                                                       |

Available N₂ was significantly affected by different treatments; the highest being in Neem Cake at 5 tonnes/ha (192.77 kg/ha); FYM at 10 tonnes/ha (190.68 kg/ha) and Adhathoda vasica twigs (184.39 kg/ha) (Table 4). While, highest available Phosphorus was in FYM at 10 tonnes/ha (15.76);
DAP at 120 kg/ha (15.46 kg/ha); DAP at 80 kg/ha (15.24 kg/ha) and Neem Cake at 5 q/ha (15.19 kg/ha). Available potassium was maximum in MOP at 80 kg/ha (149.0 kg/ha); Neem Cake at 5 quintals/ha (141.65 kg/ha); FYM at 10 tonnes/ha (137.97 kg/ha) and *A. vasica* at 15 t/ha (134.29 kg/ha).

Organic Carbon content was highest in FYM at 10 tonnes/ha (0.36%) and *A. vasica* twigs (0.35%).

Changes in available nutrient status of soil in response to the application of various organic and inorganic fertilizers in mustard is depicted in Figure 3. Percent increase or decrease in available nutrient status of soil in response to the application of various organic and inorganic fertilizers is depicted in Figure 4 and Table 5.

### Table 4. Changes in available nutrient status in response to the application of various organic and inorganic fertilizers

| Treatments | Available nutrient status * |
|------------|-----------------------------|
|            | N<sub>2</sub> (kg/ha) | P<sub>2</sub>O<sub>5</sub> (kg/ha) | K<sub>2</sub>O (kg/ha) | OC (%) |
| T<sub>1</sub> | 167.63±5.542 | 14.22±0.075 | 119.57±9.734 | 0.297±0.003 |
| T<sub>2</sub> | 190.68±7.552 | 15.76±0.341 | 137.97±3.204 | 0.363±0.008 |
| T<sub>3</sub> | 169.72±3.632 | 14.14±0.283 | 121.41±6.351 | 0.280±0.099 |
| T<sub>4</sub> | 192.77±2.096 | 15.19±0.259 | 141.65±4.885 | 0.337±0.006 |
| T<sub>5</sub> | 184.39±4.192 | 14.82±0.283 | 134.29±1.865 | 0.353±0.145 |
| T<sub>6</sub> | 176.01±3.632 | 15.24±0.196 | 121.41±3.175 | 0.270±0.001 |
| T<sub>7</sub> | 180.19±5.543 | 15.46±0.272 | 126.93±6.351 | 0.287±0.001 |
| T<sub>8</sub> | 165.53±5.543 | 14.07±0.294 | 125.09±6.646 | 0.253±0.009 |
| T<sub>9</sub> | 171.82±5.543 | 14.03±0.064 | 149.00±3.175 | 0.267±0.003 |
| T<sub>10</sub> | 159.24±5.543 | 13.62±0.164 | 106.69±1.836 | 0.237±0.005 |

*Initial available N<sub>2</sub> - 158, P<sub>2</sub>O<sub>5</sub> - 13.4, K<sub>2</sub>O - 112 kg/ha and OC – 0.24%.
4. Discussion

With the decrease in aphid incidence, there was a significant increase in seed yield during both years of study (Figures 1 and 2). However, application of higher doses of nitrogenous fertilizers viz., DAP at 80 kg/ha and 120 kg/ha, did not result in increased seed yield, as it enhanced the vegetative growth of the plant and also increased the aphid population. MOP at 40 kg/ha also gave 19.00% increase in seed yield as compared to MOP at 80 kg/ha and FYM at 5 tonnes/ha which gave 19.65% increase in seed yield (Table 3). If MOP at 40 kg/ha is applied as basal dose, it reduces aphid population by 41.11% and also seed yield by 19.00%. Neem cake also may be applied to reduce aphid incidence and increase yield, but taking its cost into consideration. In a study conducted in young peach at the three intermediate N levels, aphids (Myzus persici) populations increased over time (Zehnder &
Hunter, 2008). It remained stable at the lowest N level and decreased at the highest N level. Nitrogen deposition is expected to potentially influence, both plant resource availability and herbivore population growth. Corroborating our findings of increased aphid populations with the increase level of nitrogen application, Hosseini et al. (2015), reported enhanced aphids (Aphis craccivora) intrinsic rate of natural increase on plants fertilized with 100% of the recommended N level. Abundance and population growth rate of aphid was also positively correlated with N fertilization levels in common globe amaranth. Likewise, simulated nitrogen deposition increased Aphis nerii per capita population growth, plant foliar nitrogen concentrations and plant biomass under controlled laboratory conditions (Zehnder & Hunter, 2008). Whereas aphid (Myzus persici) number was positively correlated with young peach plant N status and vegetative growth up to the intermediate N level, it was negatively correlated with plant N status above this level, but not with vegetative growth (Sauge, Grechi, & Poëssel, 2010).

In accordance with our results, Choudhary et al. (2001) reported increase in aphid (Lipaphis erysimi and Myzus persicae) incidence in brown sarson and gobhi sarson. Increase in infestation of mustard aphid was noticed with the increase in nitrogen application level, but addition of phosphorus and potassium significantly reduced the incidence (Singh, Duss, Saran, & Singh, 1995). Increased susceptibility of plants to mustard aphid has been recorded in canola, with increased nitrogen applications (Fallahpour et al., 2015). Shorter nymphal developmental time, longer adult longevity and greater fecundity of aphids feeding on canola plants receiving higher nitrogen levels have been observed (Fallahpour et al., 2015). Potassium fertilizers are known to encourage development of thick cell wall, while application of only nitrogenous fertilizers makes the crop vulnerable to aphids. Corresponding to our study, Pandey (2010); found aphid population to increase with the application of only nitrogen or higher dosage of nitrogen. While application of phosphorus and potash with or without combination of nitrogen reduced the population build up. However, application of 120 kg ha⁻¹ nitrogen increased the yield despite higher population of mustard aphid in cold arid region of Ladakh (Pandey, 2010). Maximum aphid population was recorded in plots where NPK was applied at recommended rate through chemical fertilizers while minimum in the plot where green manure + 50 tonnes compost per hectare were applied (Singh & Nath, 2015).

Supporting our study, Rousselin et al. (2016), suggested that a higher nitrogen supply increases aphid, Myzus persici, abundance by fostering plant growth. However, they recorded a lower positive response of aphid abundance to vegetative growth of peach tree, in the case of water restriction, because under such conditions, aphids are not able to take full advantage of tree vigour.

On the contrary, all the growth and yield parameters of mustard plant were significantly affected by nitrogen fertilization. The highest seed yield and oil yield (2,961 and 1,159 kg/ha, respectively) were obtained for the crop applied with 200 kg N/ha (Keivanran & Zendi, 2014). Seasonal mean mustard aphid population was non-significantly different among canola plants receiving different levels of Nitrogen; 0, 250, 500 and 1000 mg/pot (Aslam, Razaq, & Maalik, 2004). Experimental increases in foliar nitrogen levels led to a decrease in herbivore performance in a study conducted by Zehnder and Hunter (2008, suggesting that excessive nutrient levels can limit herbivore population growth rates. Herbivore per capita population growth rates were highest at intermediate foliar nitrogen concentrations, indicating a performance cost on the highest nitrogen foliage. Wale, Schulthess, Kairu, and Omwega (2006) reported similar results from northern Ethiopia; increasing levels of N fertilizers also tended to increase pest density, plant growth and damage variables. In semi-arid eastern Amhara, the effects of fertilizer on pest damage and yield were low because of the inherent soil fertility status.

The treatments that included farm yard manure (FYM), Neem cake or A. vasica leaves showed a significant increase in available N, P and K status of soil compared with the control plots. So, the overall nutrient status of soil improved indicating the fact, that inclusion of such organically rich materials into soil helps in maintaining the soil fertility. Higher fertilizer dose, favourably influenced the plant growth and developmental characters which ultimately resulted in higher yields and lower
pest incidence. Zehnder and Hunter (2009) found that, though, there was no direct effect of foliar phosphorus concentration on insect performance, there was a strong and unexpected indirect effect. High soil phosphorus availability increased both foliar nitrogen concentrations and aphid tissue nitrogen, resulting in lower population growth rates when both soil nitrogen and phosphorus availabilities were high. They suggested that, while low nutrient availability can limit herbivore growth and reproduction, nutrient levels that exceed an organism’s nutritional requirements, i.e. an organisms’ threshold elemental ratio, can also decrease performance. Fertilizer management appears unlikely to effectively contribute to the control of Chromaphis juglandicola in commercial walnut orchards (Mace & Mills, 2015).

In our present study, application of potash fertilizers, played a direct role in reducing aphid incidence and increasing seed yield. In most of the treatments, aphid incidence adversely affected seed yield. Mustard growers can therefore be greatly benefitted by increasing the level of potash fertilizers or application of neem cake.

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**Competing interests**
The authors declare no competing interest.

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