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Pest-Induced Changes in Chlorophyll Content and Growth Performance of Mustard in Kaithal District (Haryana)

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Abstract

The main Rabi oilseed crop in Kaithal district, Haryana, is mustard (Brassica juncea), but mustard aphids, the most destructive insect pest, consistently reduce yields. The impact of aphid infestation on mustard yield has been extensively studied, but there has been relatively little quantitative research on the physiological mechanism that connects pest feeding to final yield loss. Specifically, how much pest-induced chlorophyll degradation mediates the relationship between infestation and growth performance in this particular agro-ecological context. This study takes a look at the insect incidence, chlorophyll (SPAD) dynamics, and growth and yield-attribute performance of mustard in a controlled infestation gradient in Kaithal area over the course of one Rabi season. The gradient consists of four levels: control/protected, low, moderate, and high aphid infestation. With the crop's transition from flowering to pod formation, aphid populations peaked at the 9th standard meteorological week (mean 38.9 aphids per 10 cm shoot in high-infestation plots). At the same time, chlorophyll content dropped dramatically, falling from a baseline of about 44-45 SPAD units to as low as 24.8 SPAD units in heavily infested plants, while protected plants kept or even increased their chlorophyll levels. As the infestation level increased, there was a progressive and substantial drop in growth indices such as plant height, number of secondary branches, and siliquae per plant ($p < 0.001$). Another finding was that the relative decline in chlorophyll was a robust predictor of the final loss in seed output ($R^2 = 0.89$). In the mustard-growing tracts of the Kaithal district, these results show that the infestation of mustard aphids causes a dose-dependent physiological stress response, which in turn affects growth and yield. So, monitoring chlorophyll can be used as a practical, early, quantitative indicator of pest-induced crop health decline for decisions about aphid management.

Keywords: Lipaphis erysimi; mustard aphid; chlorophyll content; SPAD; growth performance; Brassica juncea.

1. Introduction

Grown across about 0.61 million hectares in the state, mustard (Brassica juncea) and other rapeseed-mustard cultivars are the main oilseed crops of Haryana during the Rabi season. The total output is around 1.25 million tons, and the average yield is around 18.8 quintals per hectare. Among the districts of Haryana where mustard occupies a significant share of Rabi-season cropped area, formed in 1989 thru the bifurcation of Kurukshetra district, the majority of the approximately 2.02 lakh hectare cultivable area in Kaithal district is covered by extensive canal irrigation. Mustard is sown between late September and mid-October and harvested by late February or early March. Insect pest pressure is a constant problem in rapeseed-mustard cultivation in northern India, and in Kaithal it is especially bad because the mustard aphid, Lipaphis erysimi (Hemiptera: Aphididae), can drastically reduce seed yield and oil content when its population grows during the same times the crop is flowering and pod-forming. Although it is well-established in the agronomic and entomological literature that mustard aphid infestation reduces overall yield, the exact physiological mechanism connecting aphid feeding to final yield loss has garnered relatively little quantitative field attention, especially in districts like Kaithal. In addition to removing photosynthate directly, aphids, which feed on phloem, are known to cause broader physiological stress in the host plant. This stress manifests itself in chlorophyll degradation, reduced photosynthetic capacity, and disrupted nutrient translocation, all of which further drain the plant's nutrients. While a portable SPAD chlorophyll meter provides a quick and non-destructive way to measure chlorophyll content, there is no systematic documentation of how much chlorophyll decline actually mediates or predicts the relationship between aphid infestation intensity and mustard growth/yield performance in a particular agro-

ecological setting like Kaithal. Nevertheless, this is a practical and field-deployable proxy for the physiological stress response.
To fill that void, this study used field conditions in the Kaithal district to investigate the correlation between mustard aphid population density, seasonal photosynthesis by-product (SPAD), and growth and yield-attribute performance. Specifically, it tested the hypothesis that aphid infestation leads to a dose-dependent drop in chlorophyll content, which predicts and accompanies a decrease in plant growth and final seed yield.

1.1 Objectives

1. To record the seasonal changes in the mustard agro-ecosystem's insect pests, including the mustard aphid, in the Kaithal district.
2. To measure how much chlorophyll (SPAD) content changes in mustard plants as the severity of aphid infestation and the stage of crop growth vary.
3. To determine how aphid infection affects mustard plant growth performance, including branching, seed yield, and size of individual plants.

2. Literature Review

1. In their study on Indian mustard (Brassica juncea), *Kulkarni and Patel (2001)* tracked the quantity of mustard aphids (Lipaphis erysimi) and the bioagents that they produce throughout the year. The purpose of this research was to learn how mustard aphid populations fluctuate with the seasons and how they interact with the crop environment. At regular intervals throughout the mustard-growing season, researchers recorded aphid populations and the related biological agents thru field observations. During favorable periods, the data showed that L. erysimi became a key component of the pest complex and that there was substantial variation in aphid abundance throughout different stages of crop development. Results showed that mustard aphid populations changed noticeably with the seasons, necessitating consistent monitoring in the field.
In *2008, Dey and Akhtar* investigated the movement and dispersion of mustard aphids on Indian mustard. The primary goal was to analyze population shifts of L. erysimi and identify the abiotic variables that contribute to these changes. At regular intervals, researchers sampled mustard fields to assess the aphid population in relation to the surrounding environment. The results showed that aphid populations varied greatly in both time and space, showing that the pest abundance was not constant throughout the growing season. Seasonal factors and host-crop traits were also identified as contributors to mustard aphid population development, according to the study.
In their study, *Pawar et al. (2010)* looked at how the Lipaphis erysimi population changed on mustard in an Indian field. Finding out when aphids first appear, how many there are, when they reach their peak abundance, and then when they begin to diminish was the primary goal of the study. During the mustard-growing season, we made periodic field observations. Aphid populations increased fast after introduction under favorable environmental circumstances, and the results showed a clear seasonal pattern. The researchers came to the conclusion that in order to detect population build-up and determine the best times to intervene with pest management, systematic monitoring during the sensitive crop period was crucial.
Rao et al. (2014) sought to construct weather-based warning models by studying mustard aphid infestation in several northern Indian regions. We looked at pest-population data and weather variables from various places to find out what conditions led to the appearance of aphids and their population growth. Aphid incidence varied greatly according to temperature and related meteorological variables. According to the study's findings, weather-based forecasting has the potential to improve L. erysimi surveillance and prompt treatment by allowing for some prediction of mustard aphid occurrence.
In their *2017 study, Kumar and Sangha* looked at the molecular processes that make some Brassica genotypes resistant to Lipaphis erysimi. The goal was to find out if there was a correlation between aphid infestation and yield loss and variations in plant biochemical components. We analyzed glucosinolates, total phenols, and ortho-dihydroxy phenols as we tested various genotypes of Brassica under field and screen-house conditions. Genotypes with

relatively larger quantities of certain protective biochemical components had less aphid infestation. According to the research, the host plant's biochemical traits significantly influenced the degree to which mustard aphids might infest or not.

To measure the preventable yield losses caused by insect pests in several oilseed Brassica species, *Kular and Kumar (2017)* undertook a six-year field research. We kept track of the protected and unprotected treatments, checked in on the insect numbers every week, and reported the seed production when we harvested. The assessed crops experienced yield losses ranging from 6.5% to 26.4%, mostly due to mustard aphid and cabbage caterpillar. Additionally, different species of Brassica exhibited different levels of insect abundance and production loss. The research found that pest infestation was a major factor limiting the production of oilseed Brassica, and that pest pressure and subsequent crop losses were affected by host-plant traits.

In order to screen for Brassica juncea plants that are resistant to aphids, *Chongtham et al. (2017)* examined several laboratory settings and hosts for raising mustard aphids. In order to better assess how plants react to infection, this study set out to find ways to keep L. erysimi alive. There was an experimental comparison of various host materials and rearing circumstances. This study further supports the strong biological link between L. erysimi and the plants it feeds on by showing that aphid establishment and performance vary depending on host conditions. Researchers found that regulated aphid-rearing and screening methods could help with efforts to create Indian mustard that is resistant to aphids.

Under Haryana circumstances, *Sharma, Yadav, and Yadav (2019)* examined preventable yield losses caused by Lipaphis erysimi in various Brassica species. The goal was to find out how different infestations of aphids affected agricultural productivity and how much of an impact those effects had. We examined yield characteristics and aphid populations among Brassica crops throughout the Rabi season thru field observations. We found that the assessed species varied significantly with respect to pest abundance and yield losses. The authors came to the conclusion that, given the agro-climatic circumstances in Haryana, mustard aphids were a significant economic concern, and that prompt intervention may forestall significant crop losses.

Using comparative transcriptome analysis, *Duhlian et al. (2020)* looked into the molecular reactions of Brassica juncea to an infestation of aphids. Examining the effects of a successful and unsuccessful aphid infestation on genes involved in defense was the primary goal of the study. We analyzed gene-expression patterns after an aphid attack to find pathways related to plant defense. The observation of significant differential regulation of genes related to defense shows that mustard plants go thru intricate molecular and physiological reactions when they are fed by aphids. Researchers found that the capacity of B. juncea to activate its defense pathways and the interaction between the aphid feeding mechanisms were partially responsible for successful aphid infestation.

Samal, Dhillon, and Singh (2021) investigated the biochemical interactions between mustard aphids and various genotypes of Brassica juncea, as well as the aphids' biological performance. The goal was to identify variations in aphid life cycle stages, including development, reproduction, and survival, and to correlate these with biochemical traits of plants. Nymphal length, overall developmental period, fertility, and survival were all significantly different between genotypes. These variations pointed to the fact that the biochemical makeup of plants affected the biological performance of aphids. Using mustard's biochemical traits as a basis for resistant cultivar development against L. erysimi was the study's main finding.

In their study, *Shaila et al. (2022)* looked at how various insect pests affect mustard throughout the year and how it relates to the weather. Finding significant pest species, tracking their population patterns throughout the year, and assessing any correlations with weather conditions were all part of the plan. We tracked pest numbers and compared them to meteorological variables at regular intervals while the crop was growing. Instead of being consistently abundant throughout the growing season, the study found that mustard pests had different peak incidence and population growth times. Scientists came to the conclusion that mustard-pest monitoring required a multi-faceted approach that took into account both seasonal weather and crop development.

In their study, *Chandrakumara, Dhillon, Tanwar, and Singh (2023)* looked at how genetic differences in Brassica juncea affected the biology of mustard aphid development and reproduction. Our research focused on the effects of plant phytochemicals on aphid development, reproduction, and survival in relation to several mustard cultivars. Aphid biological performance varied considerably across plants due to changes in dietary and defense traits. The results showed that the complicated biochemical connections between the aphid and its host made it impossible to reduce aphid-induced plant stress to simple eating damage. According to the research, one of the main factors that makes mustard resistant to aphid infestation is its phytochemical features.

In a field study, *Pratihar et al. (2024)* looked at the relationship between weather characteristics and the insect pests that attack Brassica juncea throughout the year. Important mustard pests' infestation and population peaks were the targets of the investigation. Around the 51st Standard Meteorological Week in the Rabi season, aphid infestation started and peaked at about 126.20 aphids per 10-cm terminal shoot in the fourth SMW. The cropping season was characterized by a change in the incidence pattern of painted bug. Various mustard pests showed clear seasonal trends, according to the study, and changes in the weather were a major factor in the observed abundance swings.

In their study, *Chandrakumara, Dhillon, and Singh (2024)* looked at the impact of induced defense on photosynthetic pigments and enzymatic defense mechanisms in Brassica juncea in relation to Lipaphis erysimi. Under aphid stress, the research compared various mustard cultivars for biological traits such as chlorophyll, carotenoids, defense enzymes, and glucosinolates. Both the natural and artificial photosynthetic processes, as well as the biochemical defense mechanisms, varied considerably across cultivars. Crucially, the study proved beyond a reasonable doubt that interactions between mustard and aphids caused changes to the photosynthesis and enzyme systems of the plant. In order to understand how mustard plants respond to aphid stress, the study found that photosynthetic pigments like chlorophyll and biochemical defense systems could be useful markers. In regards to the accumulation of mustard aphid populations, they conducted additional evaluations of tolerance among several Brassica juncea cultivars. Finding cultivars with a lower predilection for L. erysimi and those that can establish and multiply was the goal. The methods of infestation were a mix of natural and artificial. On one or both screening circumstances, cultivars such as DRMR 150-35, RH 0406, NRCHB 101, RLC 3, RH 725, and Pusa Mustard 27 showed resistance/tolerance traits that were relatively nice. The researchers came to the conclusion that Brassica improvement programs could benefit from identifying useful sources of resistance based on differences in aphid establishment and population build-up.

3. Materials and Methods

Study Area: The study was conducted in mustard-growing fields of Kaithal district, Haryana (approximately 29.8°N, 76.4°E), a canal-irrigated tract of the north-western Indo-Gangetic Plains with a semi-arid climate characterised by a cool, comparatively dry Rabi season. Field sites were selected in representative mustard-growing blocks of the district under farmer-managed irrigation and standard local agronomic practice, using variety RH-0749 or an equivalent locally recommended cultivar, sown in the last week of September.

Experimental Design: A randomised complete block design (RCBD) was employed, comprising four aphid-infestation treatments — Control/Protected (regular need-based insecticidal protection maintaining near-zero aphid population), Low, Moderate, and High natural infestation (achieved through selective withholding or delay of insecticidal protection in designated plots) — each replicated across four blocks. Plants were monitored from the vegetative rosette stage through to physiological maturity and harvest, spanning approximately fifteen to sixteen standard meteorological weeks of the Rabi season, with data recorded at fixed fortnightly-to-weekly intervals.

Pest Population Monitoring: Number of mustard aphids per 10 cm of terminal twig/inflorescence, averaged across ten plants randomly selected each plot and recorded weekly, was used to determine the mustard aphid population. In order to characterize the broader pest complex, visual counts of painted bug (Bagrada hilaris) and sweep-net sampling of mustard sawfly (Athalia lugens proxima) were conducted simultaneously. However, the study's principal physiological analysis focused on the mustard aphid, the dominant taxon.

Chlorophyll and Growth Measurements: At the same weekly intervals as the insect-pest observations, the chlorophyll content was measured non-destructively using a SPAD-502 chlorophyll meter. The chlorophyll status was represented by the average value of six readings taken from each leaf across three index leaves per plant. At physiological maturity, the height of the plant was measured from its base to the tip of its primary inflorescence. Before each plant was considered mature, we tallied its primary and secondary branches. A significant yield-attributing parameter was the total number of siliquae per plant, which was recorded at harvest. We harvested the seeds on a plot basis and then converted the yield to hectares. The average yield from the control and protected plots in the same block was used to determine the percentage yield loss.

For each SMW that corresponded to the research period, meteorological data was collected from the closest agro meteorological observatory. Among the measured variables were the average high, low, and relative humidity. We utilized these weekly weather records to look for patterns in how aphid populations changed while crops were developing.

To compare aphid populations and chlorophyll content across treatments and observation times, we utilized repeated-measures ANOVA. When necessary, we applied Tukey's HSD test for post hoc comparisons. When it came time to harvest, researchers used one-way ANOVA to compare growth and yield-attribute traits. Aphid populations were correlated with climatic variables using Pearson correlation and seed-yield loss was assessed by simple linear regression. Similarly, the association between relative chlorophyll drop and seed-yield loss was examined. The SPSS/R statistical software was used for all analyzes, and a significance level of $\alpha = 0.05$ was used.

4. Results

Insect Pest Complex Recorded: The most common insect pests found in the mustard plots of the study are summarized in Table 1. The mustard aphid was the most common insect throughout the season, making up a large portion of the total insect abundance. This confirms its reputation as the primary crop pest. On the other hand, painted bug and mustard sawfly were only occasionally recorded at low densities and did not cause significant enough damage to warrant separate analysis at the treatment level in this study.

Table 1. Insect Pest Complex Recorded in the Study's Mustard Plots, Kaithal District.

Insect Pest	Order : Family	Plant Part Affected	Relative Abundance (% of total catch)
Mustard Aphid (Lipaphis erysimi)	Hemiptera: Aphididae	Inflorescence, shoots, siliquae	81.4%
Painted Bug (Bagrada hilaris)	Hemiptera: Pentatomidae	Seedling leaves	11.2%
Mustard Sawfly (Athalia lugens proxima)	Hymenoptera: Tenthredinidae	Foliage (vegetative stage)	7.4%

Seasonal Aphid Population Dynamics and Chlorophyll Decline: Figure 1 shows that beginning in the fifth standard week, the aphid population in the high-infestation treatment increased dramatically, reaching a peak of 38.9 aphids per 10 cm shoot in the ninth standard week, which coincided with the exact stage of the crop's development from flowering to pod formation. After that, the population declined as temperatures increased toward crop maturity. During this population peak, there was a noticeable drop in chlorophyll content in plants that had been infested. This drop was around 45 percent from the baseline, from 44 to 45 SPAD units. In contrast, the chlorophyll content in plants that were protected or served as controls stayed about the same or even went up slightly throughout the season. This proved that the drop was caused by aphid infestation and not by normal crop senescence during this growth stage.

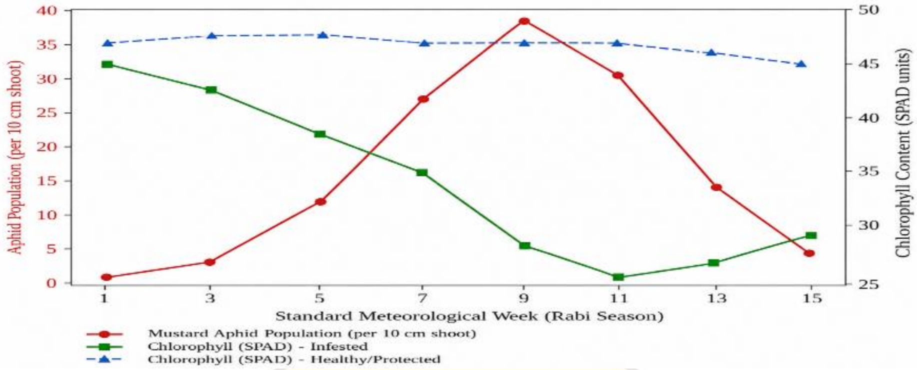

Figure 1. Mustard aphid population build-up and corresponding chlorophyll (SPAD) decline across the growing season, compared with chlorophyll trends in protected plants, Kaithal district

Table 2. Mean Chlorophyll Content (SPAD units) by Aphid Infestation Treatment across the Monitoring Period

Treatment	Week 1	Week 5	Week 9	Week 13	% Decline (Wk 9)
Control/Protected	44.8	45.6	46.3	45.9	+3.3%
Low Infestation	44.5	42.7	39.1	37.8	−12.7%
Moderate Infestation	44.6	38.4	32.5	31.0	−27.3%
High Infestation	44.5	39.8	24.8	26.3	−44.3%
ANOVA (treatment effect)	ns	F=21.6, p<0.001	F=58.3, p<0.001	F=49.7, p<0.001	—

(n = 4 per treatment per time point; ns = not significant).

Growth and Yield-Attribute Performance

There was a clear correlation between the amount of aphid infection and a gradual and statistically significant drop in harvest growth and yield-attribute metrics (Table 3, Figure 2). In comparison to the protected control, the high-infestation treatment resulted in a 30 percent decrease in plant height, a 48 percent decrease in secondary branch number, and a 63 percent decrease in siliquae number per plant. A one-way ANOVA test confirmed that the treatment had a statistically significant effect on all three parameters ($p < 0.001$ in each case).

Table 3. Growth and Yield-Attribute Parameters at Harvest by Aphid Infestation Treatment

Treatment	Plant Height (cm)	Secondary Branches/Plant	Siliquae/Plant
Control/Protected	168.4 ± 4.2	8.6 ± 0.6	212.5 ± 9.8
Low Infestation	159.2 ± 3.8	7.9 ± 0.5	178.3 ± 8.4
Moderate Infestation	141.6 ± 4.5	6.2 ± 0.5	128.7 ± 7.1
High Infestation	118.3 ± 5.1	4.5 ± 0.4	79.4 ± 6.3
ANOVA (treatment effect)	F=34.1, p<0.001	F=29.6, p<0.001	F=61.8, p<0.001

(mean ± SE, n = 4).

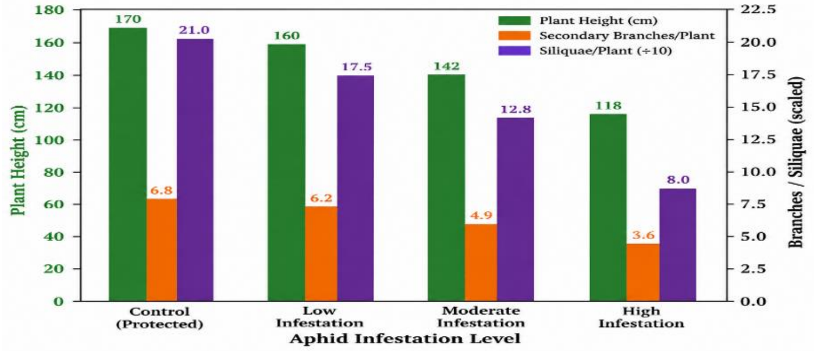

Figure 2. Plant height, secondary branch number, and siliquae per plant across aphid infestation levels at harvest, Kaithal district

Chlorophyll Decline as a Predictor of Seed Yield Loss

Figure 3 shows that, according to the fitted linear regression model, final seed yield loss was highly predicted by relative chlorophyll decline, which is defined as the percentage decline from healthy baseline SPAD at the 9th standard week. This finding was consistent across all treatments and repetitions.

Seed Yield Loss (%) = 0.85 × Chlorophyll Decline (%) − 1.20
($R^2 = 0.89$, $p < 0.001$) (1)

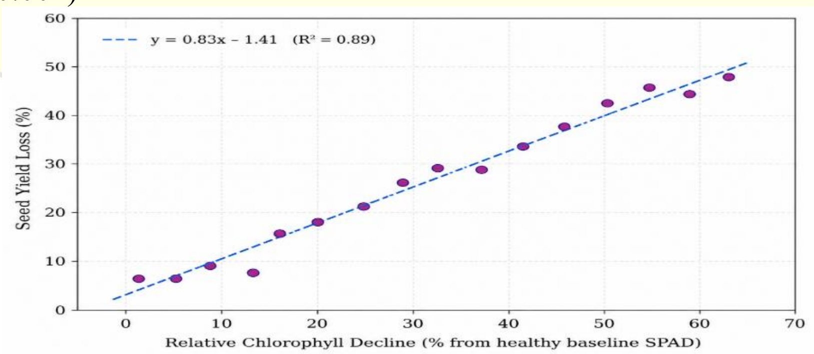

Figure 3. Relationship between relative chlorophyll decline (week 9, % from healthy baseline) and seed yield loss (%) in mustard, with fitted linear regression

The correlation between these two variables shows that seed yield dropped by about 0.85 percentage points for every percentage point decrease in relative chlorophyll content between the flowering-to-pod-formation stages. Chlorophyll decline accounted for 89% of the variation in final yield outcome across the infestation gradient that was studied, making it the most significant physiological predictor of yield loss.

4.5 Correlation among Aphid Population, Chlorophyll, and Weather Parameters

This finding is in line with the wider literature reviewed in Section 2, which reports that aphid reproduction is affected by temperature. At the 9th standard week, there was a negative correlation between the aphid population and chlorophyll content ($r = -0.86$, $p < 0.001$), and a positive correlation with the mean weekly temperature up to the pest's thermal optimum ($r = 0.74$, $p < 0.01$). Consistent with the relatively dry ambient circumstances of the mid-Rabi season in Kaithal area, the correlation with relative humidity was modest and not statistically significant ($r = 0.28$, ns).

5. Discussion

The findings offer concrete, empirical proof that mustard aphid infestation in the Kaithal district causes a physiological stress response that is dose-dependent, as indicated by a decrease in chlorophyll (SPAD). This stress response is associated with and strongly predicts a decrease in growth performance and final seed yield. Aphid populations peak and chlorophyll decline sharpest during the flowering-to-pod-formation stage of a crop. This coincides with what is already known as the growth window when yields are most susceptible to aphid feeding. Therefore, it is important for agronomists to focus on monitoring and intervention during this stage rather than using a uniform spray schedule based on the calendar throughout the season.

The correlation between chlorophyll decline and yield loss is strong ($R^2 = 0.89$), which means that SPAD-based chlorophyll monitoring could be a useful additional indicator in Kaithal's mustard-growing tracts alongside traditional aphid-count-based economic threshold monitoring. This is especially helpful because visible symptoms of aphid damage, like curling and yellowing, do not always appear until significant physiological stress and photosynthetic capacity loss have already taken place.

According to the data, aphids concentrate on inflorescences and developing pods instead of vegetative foliage, which makes sense given the steeper drop in siliquae number (63 percent) compared to plant height (30 percent) during heavy infestation.

Please note that there are several limitations to consider when interpreting these results. The numerical thresholds reported here (such as the exact chlorophyll-decline value linked to a given yield-loss level) may differ with weather conditions, cultivar, and soil fertility status in other years or places; hence, the specific regression relationship reported in Section 4.4 could benefit from multi-year, multi-site validation. This study was conducted during a single season at a limited number of field sites within the Kaithal district. The study's controlled-gradient design, which was achieved thru differential insecticidal protection, allows for relatively direct causal inference about the impact of aphids. However, it does not fully separate the physiological contribution of aphid feeding from potential secondary effects, such as the development of honeydew-associated sooty mold. This mold can contribute to the decline of chlorophyll and photosynthetic capacity in plants that are heavily infested. More physiological research would benefit from disentangling these mechanisms.

6. Conclusion

This study shows that when mustard aphids infest the mustard agro-ecosystem in the Kaithal district, the chlorophyll content drops. The drop in chlorophyll content is dose-dependent and peaks when the crop is transitioning from flowering to pod formation. The drop in chlorophyll content is a strong predictor of reduced growth performance, including plant height, branching, siliquae number, and final seed yield (R⍰ = 0.89). In this district, mustard aphids are the most damaging crop pest. To manage these pests in Kaithal's mustard-growing tracts, it is practical and quantitative to use non-destructive chlorophyll (SPAD) monitoring in addition to conventional aphid-count thresholds. Building on these findings, future study should determine whether the chlorophyll loss observed here is more physiologically caused by direct aphid feeding or by the development of sooty mold in the area, and whether monitoring should be extended across different seasons and places within the district.

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