CHAPTER–4
EXPERIMENTAL
RESULTS
CONTENTS

EXPERIMENTAL RESULTS

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EXPERIMENTAL RESULTS

It has been mentioned in Materials and Methods section that the two experiments (1 and 2) and (3 and 4) were conducted on the same lines with difference of irrigated and non-irrigated conditions. The results of Experiment 1 and 2, and Experiment 3 and 4 are described together in the following pages. The data of Experiment 1 (Tables 7-34), Experiment 2 (Tables 35-62), pooled analysis of Experiment 1 and 2 (Tables 63-71), Experiment 3 (Tables 72-104), Experiment 4 (105-137), pooled analysis of Experiment 3 and 4 (Tables 138-146) and Experiment 5 (Tables 147-180) are given at the end of the thesis.

4.1 Experiment 1 and 2

In these experiments concentrations of ethrel applied at 60d after sowing were 0, 100, 200, 400 and 600 μL/L on Alankar and PBM16 cultivars of mustard. Growth characteristics, plant height, plant leaf area, leaf area index, specific leaf area, specific leaf weight, plant dry weight, dry weight and its percent distribution in leaf, stem and pod, leaf fresh weight, leaf turgid weight and leaf relative water content; biochemical characteristics, N concentrations and its accumulation were recorded at 80, 100 and 120 DAS. Physiological characteristics, net photosynthetic rate, stomatal conductance, internal CO₂ concentration, transpiration rate, carboxylation efficiency, photosynthetic water use efficiency and plant water use efficiency were recorded at 80 and 100 DAS. At harvest pod number, seed number, 1000 seed weight, seed yield, biological yield, harvest index, oil yield, oil content, acid value, iodine value and saponification value of oil were determined.

4.1.1 Growth characteristics

4.1.1.1 Plant height

Plant height was significantly affected by ethrel spray and both cultivars differed each other at all growth stages. The interaction effect between ethrel
spray and cultivar was non-significant (Tables 7, 35). Similar response was noted in both the experiments.

Spraying of 200µL/L ethrel registered maximum effect on plant height and water spray recorded minimum value for plant height at all growth stages. Among the cultivars, Alankar was taller than PBM16 at all sampling times (Tables 7, 35) in Experiment 1 as well as in Experiment 2.

4.1.1.2 Plant leaf area

Crop canopy, which is represented by leaf area, was significantly affected by ethrel spray and cultivars also differed significantly at all sampling times in the two experiments. The interaction effect between these two was found significant at 80 DAS in Experiment 1 and 80 and 100 DAS in Experiment 2 (Tables 8, 36).

A concentration of 200µL/L ethrel showed maximum value at all three growth stages and significantly minimum value was recorded for water sprayed under irrigated and non-irrigated conditions.

Alankar showed maximum leaf area as compared to PBM16 at all sampling stages in the two experiments. It was observed that 200µL/L ethrel spray on Alankar gave maximum value and water spray on PBM16 gave minimum value at 80 DAS in Experiment 1. Similar effect was noted at 80 and 100 DAS in Experiment 2 (Tables 8, 36).

4.1.1.3 Leaf area index

Leaf area index was significantly affected by ethrel spray and cultivars differed significantly at all sampling times. Interaction effect between ethrel spray and cultivar was significant only for 80 DAS. A similar response was noted in both the experiments (Tables 9, 37).

Significantly maximum value was recorded with 200µL/L ethrel spray at every growth stage and minimum value was found in water spray. Alankar showed higher leaf area index than PBM16.
Among different interactions, 200μL/L ethrel spray on Alankar registered maximum value and minimum value was recorded in water spray on PBM16 (Tables 9, 37).

4.1.1.4 Specific leaf area

Ethrel spray significantly affected specific leaf area and cultivars differed significantly for this characteristic at all sampling times in both the experiments. The interaction effect of these two remained non-significant in both the experiments (Tables 10, 38).

Spray of 200μL/L ethrel and water gave maximum and minimum values respectively in both the experiments. Alankar showed maximum and PBM16 the minimum values.

4.1.1.5 Specific leaf weight

Values recorded in ethrel spray and cultivar differed significantly at all the sampling times in both the experiments. Interaction effect was noted to be non-significant in both the experiments (Tables 11, 39).

Significantly maximum and minimum values were recorded with water spray and 200μL/L ethrel spray respectively. The trend was similar in the two experiments, and Alankar registered higher value than PBM16.

4.1.1.6 Plant dry weight

Plant dry weight was affected by ethrel spray at every growth stage. The effect of ethrel spray on cultivars differed significantly at 80 DAS only, however, at other sampling times, the two cultivars responded equally to every spray treatment (Tables 12, 40) in Experiment 1. Highest plant dry weight was recorded with 200μL/L ethrel spray at all sampling times, while the lowest value was found in water sprayed control.

Alankar showed maximum plant dry weight as compared to PBM16. Among interactions, 200μL/L ethrel spray on Alankar proved best and gave significantly maximum value as compared to other interactions. Minimum value was noted in water sprayed on PBM16.
4.1.1.7 Dry weight of different plant parts

4.1.1.7.1 Leaf dry weight

Ethrel spray significantly affected leaf dry weight at all sampling times. Ethrel spray on the two cultivars significantly differed at 80DAS in Experiment 1 and at 100 DAS in Experiment 2 (Tables 13, 41).

Maximum leaf dry weight was recorded with 200μL/L ethrel spray at all sampling times in both the experiments. Significantly minimum value was found in water sprayed control treatments.

Among the cultivars, Alankar showed maximum value as compared to PBM16 in the two experiments. Among interactions, 200μL/L ethrel spray on Alankar proved best and gave significantly higher value while the lowest value was recorded in water sprayed on PBM16.

4.1.1.7.2 Stem dry weight

Stem dry weight was significantly affected by ethrel spray at all sampling times in both the experiments. Effect of ethrel spray on the two cultivars significantly differed at 80 and 100 DAS in Experiment 1, whereas the cultivars responded similarly to the concentrations of ethrel in Experiment 2 at all sampling times (Tables 14, 42).

In both the experiments, 200μL/L ethrel spray resulted in maximum value for stem dry weight, while minimum value was found in water sprayed control.

Alankar registered higher dry weight than PBM16 at all sampling times under irrigated and non-irrigated conditions. Regarding the interaction between ethrel spray and cultivar, it was observed that 200μL/L ethrel spray on Alankar gave maximum value at 80 and 100 DAS.

4.1.1.7.3 Pod dry weight

Effect of ethrel spray was significant at all sampling times and the interaction effect between spray and cultivar was found significant at 100 DAS in Experiment 1 and 2 (Tables 15, 43).
A 200μL/L ethrel spray gave highest value at all sampling times. Significantly lowest value was recorded for water spray control. At all growth stages, Alankar showed higher value than PBM16.

Among the interactions, 200μL/L ethrel spray on Alankar gave maximum value. However, minimum value was registered with water spray on PBM16 (Tables 15, 43).

4.1.1.8 Per cent distribution of dry weight in plant parts

4.1.1.8.1 Leaf

Effect of ethrel spray was found significant at all sampling times in both the experiments. The two cultivars differed significantly at 100 and 120 DAS in Experiment 2. The interaction effect between ethrel spray and cultivar was non-significant in both the experiments (Tables 16, 44).

Significantly maximum value was recorded with 200μL/L ethrel spray at every growth stages, while minimum value was found with water spray.

Value recorded for Alankar was higher than PBM16, when they differed significantly (Tables 16, 44).

4.1.1.8.2 Stem

Effect of ethrel spray was significant at all the three growth stages in both the experiments. Similarly, cultivars differed each other significantly. The interaction effect was significant at 100 DAS in Experiment 1, but it was non-significant at all sampling times in Experiment 2.

Per cent stem dry weight decreased with the increase in ethrel concentration at all growth stages and water-sprayed control registered maximum value. Significantly minimum value was recorded with 200μL/L ethrel spray. The trend was similar in both the experiments.

At all growth stages, PBM16 gave more value than Alankar. The interaction effect of water spray and PBM16 gave maximum value. Minimum value was given by 200μL/L ethrel sprayed on Alankar (Tables 17, 45).
4.1.1.8.3 Pod

Distribution of dry weight towards pods was significantly influenced by ethrel spray and cultivar also differed significantly. Similar response was noted in the Experiment 1 and 2. However, interaction effect of ethrel spray and cultivar was significant at 100 DAS in Experiment 1 and non-significant at all sampling times in Experiment 2 (Tables 18, 46).

A 200μL/L ethrel spray showed maximum value and significantly minimum value was registered for water sprayed control in both the experiments.

Alankar showed higher value than PBM16 at all sampling times in both the experiments. Spray of 200μL/L ethrel on Alankar proved best and gave maximum value, while minimum value was found in water spray on PBM16 (Tables 18, 46).

4.1.1.9 Leaf fresh weight

Ethrel spray significantly affected plant fresh weight. The ethrel spray on the two cultivars was significant only at 80 DAS in Experiment 1 and non-significant in Experiment 2 (Tables 19, 47). Spray of 200μL/L ethrel gave highest value at all sampling times, while the minimum value was found with water-sprayed control.

Cultivar, Alankar, elicited maximum value as compared to PBM16. Interaction of ethrel spray and cultivar produced higher leaf fresh weight when spray of 200μL/L ethrel was done on Alankar, while the minimum value was found in water sprayed on PBM16.

4.1.1.10 Leaf turgid weight

Turgid weight of leaves was significantly affected by ethrel spray at all sampling times. Spray of ethrel on the two cultivars significantly differed at 80 DAS, whereas the two cultivars responded similarly to concentrations of ethrel in Experiment 2 (Tables 20, 48).
Spray concentration of 200μL/L ethrel showed maximum value at all sampling times in both the experiments. At all sampling times, Alankar showed maximum value as compared to PBM16 in the two experiments.

Regarding interaction effect, it was observed that 200μL/L ethrel spray on Alankar expressed maximum effect. Minimum value was observed in water sprayed on PBM16.

4.1.1.11 Leaf relative water content

Relative water content in leaf significantly responded towards ethrel spray and for cultivars at all sampling stages in both the experiments. The interaction effect of these two was found significant at 80 DAS in Experiment 1 and at 80 and 100 DAS in Experiment 2 (Tables 21, 49).

Maximum value was recorded for 200μL/L ethrel at all growth stages and significantly minimum value was found in water sprayed control. Alankar showed higher values than PBM16 in both the experiments.

Regarding the interaction between ethrel spray and cultivar, it was noted that 200μL/L ethrel spray on Alankar expressed the maximum value at 80 DAS in Experiment 1. Similarly, 200μL/L ethrel on Alankar proved best at 80 and 100 DAS in Experiment 2 (Tables 21, 49).

4.1.2 Physiological characteristics

4.1.2.1 Rate of photosynthesis

Rate of photosynthesis significantly reciprocated towards ethrel spray and for cultivar at all sampling stages. The interaction effect between ethrel spray and cultivar remained non-significant. Similar response was noted in both the experiments (Tables 22, 50).

Spraying concentration of 200μL/L ethrel gave maximum value at all sampling stages and significantly minimum value was found in water-sprayed control in both the experiments. Alankar showed higher value than PBM16 at all sampling times (Tables 22, 50).
4.1.2.2 Stomatal conductance

Stomatal conductance was significantly influenced by ethrel spray and cultivars differed significantly at all growth stages, but the interaction effect between ethrel spray and cultivar was non-significant (Tables 23, 51) in both the experiments.

Highest value for stomatal conductance was recorded with 200μL/L ethrel spray at all growth stages and significantly lowest value was found with water-sprayed control in Experiment 1 and Experiment 2. Alankar showed higher value than PBM16.

4.1.2.3 Internal CO₂ concentration

Effect of ethrel spray was significant on internal carbon dioxide concentration and cultivars also differed significantly at all sampling times. The interaction effect was non-significant (Tables 24, 52). A similar response was observed in both the experiments.

Maximum value for internal carbon dioxide concentration was noted with 200μL/L ethrel spray and Alankar exhibited higher values at all sampling times (Tables 24, 52).

4.1.2.4 Transpiration rate

In both the experiments, effect of ethrel spray and cultivar difference was significant at all growth stages, while the interaction effect between these two was found significant at 80 DAS (Tables 25, 53).

At all growth stages, 200μL/L ethrel spray gave maximum value. Significantly minimum value was recorded in water sprayed control. Alankar showed higher value as compared to PBM16 at all sampling stages.

Among various interactions, 200μL/L ethrel spray on Alankar expressed the maximum value. Significantly minimum value was given by water-sprayed control x PBM16 (Tables 25, 53).
4.1.2.5 Carboxylation efficiency

Effect of ethrel spray was found significant at all sampling times and cultivars differed significantly at 100 DAS in Experiment 1 and at all stages in Experiment 2. The interaction effect in both the experiments remained non-significant (Tables 26, 54).

Value recorded with 200μL/L ethrel spray was significantly maximum at all growth stages. Minimum value was recorded with water-sprayed control. Alankar showed maximum value as compared to PBM16 at all sampling stages.

4.1.2.6 Photosynthetic water use efficiency

Photosynthetic water use efficiency was significantly affected by ethrel spray and cultivars differed significantly at all growth stages. The interaction effect was significant at 80 DAS (Tables 27, 55) in both the experiments.

Spraying concentration of 200μL/L ethrel gave highest value at all growth stages. Significantly lowest value was found with water-sprayed control treatment. Value recorded for Alankar was significantly higher as compared to PBM16 at all growth stages.

Regarding the interaction effect, it was observed that 200μL/L ethrel spray on Alankar gave maximum value and was at par with that for 200μL/L ethrel spray on PBM16 at 80 DAS. The effect was similar in both the experiments (Tables 27, 55).

4.1.2.7 Plant water use efficiency

Plant water use efficiency significantly reciprocated towards both ethrel spray and for cultivars difference at all sampling stages in the Experiment 1 and 2. The interaction effect was significant only at 80 DAS in Experiment 1 and non-significant in Experiment 2 (Tables 28, 56).

Values recorded for 200μL/L ethrel spray in Experiment 1 and 2 were significantly maximum at all growth stages and minimum values were found in water-sprayed control. Alankar proved better than PBM16.
Interaction effect of 200μL/L ethrel spray on Alankar registered higher water use efficiency, which differed critically from all other combinations.

4.1.3 Biochemical characteristics

4.1.3.1 N content

Nitrogen content in plant tissues significantly responded towards ethrel spray and cultivars also differed significantly at every sampling time in both the experiments. The interaction effect was found to be significant only at 80 DAS in Experiment 1 and at all sampling times in Experiment 2 (Tables 29, 57).

Spray of 200μL/L ethrel and Alankar registered maximum values at all sampling times in the two experiments. Water-sprayed control gave significantly minimum values.

Among different interactions, 200μL/L ethrel spray on Alankar gave maximum value at 80 DAS in Experiment 1 but in Experiment 2, this interaction gave at par value with that for 200μL/L ethrel on PBM16 at 100 DAS.

4.1.3.2 N accumulation

Nitrogen accumulation was significantly influenced by both ethrel spray and for cultivars at all sampling times and the interaction effect was non-significant in Experiment 1. The interaction effect in Experiment 2 was significant at 80 and 100 DAS (Tables 30, 58).

Maximum value was recorded for 200μL/L ethrel spray at all sampling times. Significantly minimum value was found in water sprayed control. Alankar registered maximum value.

Interaction 200μL/L ethrel on Alankar proved best at 80 and 100 DAS in Experiment 2. The values differed significantly from other combinations (Tables 30, 58).
4.1.4 Yield characteristics

4.1.4.1 Number of pods per plant

Number of pods per plant was significantly affected by ethrel spray in Experiment 1 and 2. Similarly, in both the experiments, cultivars differed significantly. The interaction effect was non-significant in both the experiments (Tables 31, 59).

Significantly maximum value was recorded for 200μL/L ethrel spray, while the minimum value was found with water-sprayed control in both the experiments.

Among the cultivars, Alankar showed higher value as compared to PBM16 in both the experiments (Tables 31, 59).

4.1.4.2 Number of seeds per pod

Number of seeds per pod was significantly affected by both ethrel spray and cultivars. The interaction effect was non-significant (Tables 31, 59) in both the experiments.

Highest value for number of seeds per pod was recorded for 200μL/L ethrel spray. Significantly lowest value was found in water sprayed control in Experiment 1 and 2. Alankar showed higher value than PBM16 (Tables 31, 59).

4.1.4.3 1000 seed weight

Effect of ethrel spray and cultivar difference was found significant, while their interaction was found to be non-significant in both the experiments (Tables 31, 59).

Maximum value was recorded for 200μL/L ethrel spray. Significantly minimum value was noted in water sprayed control. Among the cultivars, Alankar showed higher value than PBM16 (Tables 31, 59). The response was similar in both the experiments.
4.1.4.4 Seed yield

Like yield attributes, seed yield was also significantly influenced by ethrel spray and cultivar difference was also significant. But interaction between these two remained non-significant. Similar response was noted in Experiment 1 and 2 (Tables 32, 60).

Spray concentration of 200\(\mu\)L/L ethrel gave significantly maximum value. Significantly lowest value was recorded for water sprayed control in both the experiments. Alankar gave higher value than PBM16 (Tables 32, 60).

4.1.4.5 Biological yield

Biological yield significantly responded towards both ethrel spray and the cultivar. The interaction effect between ethrel spray and cultivar was found non-significant in both the experiments (Tables 32, 60).

Significantly highest value was registered for 200\(\mu\)L/L ethrel spray, while the lowest value was found in water sprayed control in Experiment 1 and 2.

Value recorded for Alankar was significantly higher as compared to PBM16 in both the experiments (Tables 32, 60).

4.1.4.6 Harvest index

Harvest index was significantly influenced by both ethrel spray and cultivars, but no significant impact was observed when these two factors interacted (Tables 32, 60). Similar response was noted in Experiment 1 and 2.

Effect of ethrel spray at 200\(\mu\)L/L gave significantly maximum value. Significantly minimum value was recorded for water sprayed control treatment. Alankar showed more value for harvest index than PBM16 in Experiment 1 and 2 (Tables 32, 60).

4.1.4.7 Oil yield

Ethrel spray significantly affected oil yield. Cultivars also differed significantly. However, interaction effect was not significant in both the experiments (Tables 33, 61).
Maximum value was recorded for 200μL/L ethrel, which differed from other values recorded in other spray treatments in both the experiments. Alankar out yielded PBM16.

4.1.5 Quality characteristics

4.1.5.1 Oil content

Effect of ethrel spray was significant individually as well as on its effects on the cultivars. Cultivars also differed significantly for the oil content (Tables 33, 61) in Experiment 1 and 2.

Spray of 200μL/L ethrel registered significantly highest oil content in both the experiments. Cultivar Alankar proved better than PBM16. This resulted in maximum oil content in Alankar sprayed with 200μL/L ethrel than any other concentrations of ethrel on either cultivars in both the experiments (Tables 33, 61).

4.1.5.2 Acid value

Effect of ethrel spray and cultivar was significant in both the experiments. The interaction effect between these two was significant in Experiment 1 and non-significant in Experiment 2 (Tables 34, 62).

Ethrel at 200μL/L concentration gave significantly maximum value and Alankar registered highest acid value in both the experiments. Interaction of 200μL/L ethrel spray x Alankar registered higher acid value, which differed critically from all other combinations in Experiment 1 (Tables 34, 62).

4.1.5.3 Iodine value

Effect of ethrel spray, cultivar and their interaction effect were non-significant in the two experiments (Tables 34, 62).

4.1.5.4 Saponification value

Saponification value was significantly reciprocated to both ethrel spray and cultivar while the interaction effect between these two remained non-significant (Tables 34, 62). Similar response was noted in Experiment 1 and 2.
Spraying concentration of 200μL/L ethrel gave maximum value. Significantly minimum value was noted for water sprayed control Alankar registered significantly higher value as compared to PBM16 (Tables 34, 62).

4.1.6 Pooled analysis of Experiment 1 and 2

Pooled analysis of the data of Experiments 1 and 2 was done to evaluate the performance of the cultivars in irrigated and non-irrigated conditions. Also the impact of ethrel spray on the two cultivars under irrigated and non-irrigated experiments was evaluated (Tables 63, 71). The data showed that there was no significant effect of irrigation and cultivars also did not differ significantly under irrigated and non-irrigated conditions. Similarly, ethrel spray was equally effective under the conditions of irrigation. The three-way interaction was found non-significant.

4.2 Experiment 3 and 4

Experiment 3 was conducted under irrigated conditions and Experiment 4 under non-irrigated conditions. These experiments were conducted to investigate the effect of leaf-applied 0, 100 and 200μL/L ethrel (selected on the basis of Experiment 1 and Experiment 2) at 60d after sowing (DAS, flowering stage) on mustard (Brassica juncea L.) cultivar Alankar grown with basally applied 0, 40, 60 or 80kg N/ha, on growth, physiological, biochemical, yield and quality characteristics determined at various sampling times as described in Experiment 1 and Experiment 2. Among physiological characteristics, 1-aminocyclopropane-1-carboxylic acid, ACC oxidase and ethylene evolution were also noted at 80 and 100 DAS samplings. Among biochemical characteristics, nitrate reductase activity was also recorded at 80 and 100 DAS samplings. Among yield characteristics, seed nitrogen content per plant, nitrogen harvest index and nitrogen yield potential were also studied at harvest. The details of the results are given below and summarized in Tables 72–137.
4.2.1 Growth characteristics

4.2.1.1 Plant height

Plant height was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. However, the interaction effect between ethrel spray and nitrogen was found significant at 80 and 100 DAS in Experiment 3, and at 80 DAS in Experiment 4 (Tables 72, 105).

At all sampling times, 200µL/L ethrel spray showed significantly maximum value, while the minimum value was recorded in water-sprayed control in the two experiments.

Maximum height was recorded with 80kg N/ha and minimum with 0kg N/ha at all sampling times in both the experiments.

Among interactions, 200µL/L ethrel spray x 80kg N/ha proved best and gave significantly maximum value. Minimum value was recorded with water sprayed control x 0kg N/ha. This was the effect in both the experiments when the effect was significant (Tables 72, 105).

4.2.1.2 Plant leaf area

Leaf area was significantly affected by ethrel spray and nitrogen application at all sampling times in both the experiments, while their interaction effect was significant at all sampling times only in Experiment 3 (Tables 73, 106).

Maximum value was recorded with 200µL/L ethrel whereas minimum value was found with water-sprayed plants at all sampling times.

At all sampling times, treatment 80kg N/ha gave significantly maximum value, while the minimum value was registered with 0kg N/ha in both the experiments.

Regarding the interaction effect, it was observed that 200µL/L ethrel spray x 80kg N/ha gave maximum value. Minimum value was recorded with water-sprayed control x 0kg N/ha (Tables 73, 108).
4.2.1.3 Leaf area index

Application of ethrel spray and nitrogen resulted into significant impact on leaf area index at all sampling times in both the experiments. But the interaction effect between ethrel spray x nitrogen was significant at all sampling days in Experiment 3 only (Tables 74, 107).

Maximum and minimum values were recorded with 200μL/L ethrel spray and water-sprayed control respectively at all sampling times. At all sampling times, treatment 80kg N/ha gave significantly maximum value, whereas minimum value was recorded with 0kg N/ha in both the experiments.

Interaction effect of ethrel spray and nitrogen produced higher leaf area index in combination of 200μL/L ethrel spray x 80kg N/ha. Minimum value was recorded with water-sprayed control x 0kg N/ha (Tables 74, 107).

4.2.1.4 Specific leaf area

The effect of ethrel spray and nitrogen proved significant at all sampling times, while their interaction effect was found non-significant in both the experiments (Tables 75, 108).

At all sampling times, 200μL/L ethrel spray gave maximum value and minimum value was recorded with water-sprayed control in both the experiments.

Application of nitrogen at 80kg N/ha exhibited maximum value and the minimum value was registered in 0kg N/ha at all sampling times in both the experiments (Tables 75, 108).

4.2.1.5 Specific leaf weight

Effect of ethrel spray and nitrogen was significant at all sampling times, while the interaction effect between these two was non-significant in both the experiments (Tables 76, 109).

At all sampling times, water-sprayed plants gave significantly maximum value, while the minimum value was recorded with 200μL/L ethrel spray.
Treatment 0kg N/ha expressed maximum value, while the minimum value was recorded with 80kg N/ha at all sampling times in both the experiments (Tables 76, 109).

4.2.1.6 **Plant dry weight**

Ethrel spray and nitrogen significantly affected plant dry weight at all sampling times in both the experiments. The interaction effect between these two was significant at all sampling times in Experiment 3 only.

Maximum value was recorded with 200µL/L ethrel spray and minimum value with water-sprayed control at all sampling times in both the experiments.

At all sampling times, 80kg N/ha gave significantly maximum value, while the minimum value was recorded with 0kg N/ha.

Interaction effect of ethrel spray and nitrogen produced higher plant dry weight in the combination of 200µL/L ethrel x 80kg N/ha. Minimum value was recorded with water-sprayed control x 0kg N/ha (Tables 77, 110).

4.2.1.7 **Dry weight of different plant parts**

4.2.1.7.1 **Leaf dry weight**

Application of ethrel spray and nitrogen resulted in significant impact on leaf dry weight at all sampling times in both the experiments. The interaction between ethrel and nitrogen was significant at 80 and 100 DAS in Experiment 3, whereas in Experiment 4, interaction effect was significant only at 120 DAS.

Maximum value was recorded with 200µL/L ethrel spray and minimum value with water-sprayed control at all sampling times in Experiment 3 and 4.

Application of nitrogen at 80kg N/ha gave significantly maximum value and differed from other treatments at all sampling times in Experiment 3 and 4.

Regarding the interaction effect, it was observed that 200µL/L ethrel spray along with 80kg N/ha proved best compared to any other combinations in both the experiments (Tables 78, 111).
4.2.1.7.2 Stem dry weight

Effect of ethrel spray and basal nitrogen application was significant at all sampling times in Experiments 3 and 4. The interaction effect was significant at 120 DAS in Experiment 3, while in Experiment 4, interaction effect was significant only at 80 DAS (Tables 79, 112).

At all sampling times, 200μL/L ethrel showed maximum value, while minimum value was recorded with water-sprayed control in both the experiments.

Treatment 80kg N/ha exhibited maximum value and the minimum value was registered with 0kg N/ha at all sampling times in both the experiments.

Among interactions, 200μL/L ethrel x 80kg N/ha gave maximum value, while the minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 79, 112).

4.2.1.7.3 Pod dry weight

Pod dry weight was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments, while their interaction effect was significant at all sampling times in Experiment 3, and at 120DAS in Experiment 4 (Tables 80, 113).

Significantly maximum value was recorded with 200μL/L ethrel spray and minimum value was found with water-sprayed control at all sampling times in Experiments 3 and 4.

At all sampling times, treatment 80kg N/ha gave significantly maximum value, while the minimum value was recorded with 0kg N/ha in both the experiments.

Interaction between ethrel spray and nitrogen produced higher pod dry weight for the combination of 200μL/L ethrel spray x 80kg N/ha. Minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 80, 113).
4.2.1.8 Per cent distribution of dry weight in plant parts

4.2.1.8.1 Leaf

Effect of ethrel spray and nitrogen was significant at all sampling times in both the experiments. But the interaction effect between these two was significant at 80 and 100 DAS in Experiment 3 and at 120 DAS in Experiment 4 (Tables 81, 114).

At all sampling times, 200μL/L ethrel spray gave significantly maximum value, while the minimum value was recorded with water-sprayed control in both the experiments.

Application of nitrogen at 80kg N/ha gave significantly higher value, whereas the minimum value was registered with 0kg N/ha at all sampling times in Experiments 3 and 4.

Regarding the interaction effect, it was observed that 200μL/L ethrel x 80kg N/ha gave maximum value, which differed critically from other combinations in both the experiments (Tables 81, 114).

4.2.1.8.2 Stem

Effect of ethrel spray and application of nitrogen was significant at all sampling times in both the experiments. The interaction effect was significant at 80 and 100 DAS in Experiment 3, whereas in Experiment 4, it was significant only at 120DAS (Tables 82, 115).

Water-sprayed plants and 200μL/L ethrel spray exhibited maximum and minimum values respectively at all sampling times in both the experiments.

At all sampling times, 0kg N/ha gave maximum value and minimum value was recorded with 80kg N/ha in Experiment 3 and 4.

Among interactions, water-sprayed control x 0kg N/ha showed maximum value, while minimum value was registered with 200μL/L ethrel x 80kg N/ha (Tables 82, 115).
4.2.1.8.3 Pod

Effect of ethrel spray and nitrogen was significant at all sampling times in Experiments 3 and 4. However, the interaction effect was significant at all sampling times in Experiment 3, whereas in Experiment 4, it was significant at 100 and 120 DAS (Tables 83, 116).

Highest per cent pod dry weight was recorded in 200μL/L ethrel spray, while minimum value was recorded in water sprayed control at all sampling times with both the experiments.

Application of 80kg N/ha resulted in significantly higher pod dry weight in both the experiments.

Regarding interaction effect, it was noted that 200μL/L ethrel x 80kg N/ha proved best and differed significantly from other combinations (Tables 83, 116) in both the experiments.

4.2.1.9 Leaf fresh weight

Leaf fresh weight was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. But the interaction between these two was found significant at 80 and 100 DAS in Experiment 3, whereas in Experiment 4, it was significant at 120 DAS (Tables 84, 117).

Highest value of leaf fresh weight was recorded with 200μL/L ethrel spray, while the minimum value was found with water-sprayed control at all sampling times in both the experiments.

Application of nitrogen at 80kg N/ha showed significantly maximum value. Minimum value was recorded with 0kg N/ha at all sampling times in both the experiments.

Regarding the interaction effect, it was observed that 200μL/L ethrel spray x 80kg N/ha proved best than any other combinations (Tables 84, 117) at sampling times when effect was significant.
4.2.1.10 Leaf turgid weight

Effect of ethrel spray and application of nitrogen was significant at all sampling times in both the experiments. The interaction effect was significant at 80 and 100 DAS in Experiment 3, whereas in Experiment 4, it was significant only at 120 DAS.

At all sampling times, 200μL/L ethrel showed significantly maximum value. Minimum value was registered with water-sprayed control at both the experiments.

At all sampling times, 80kg N/ha recorded maximum value and the minimum value was noted with 0kg N/ha.

Among interactions, 200μL/L ethrel x 80kg N/ha gave maximum value, which differed significantly from other values. Minimum value was recorded with water-sprayed control x 0kg N/ha (Tables 85, 118).

4.2.1.11 Leaf relative water content

Relative water content in leaf tissues was significantly affected by both ethrel spray and nitrogen at all sampling times in both the experiments. However, the interaction effect between these two was found significant at 80 and 120 DAS only in Experiment 4 (Tables 86, 119).

Spray of 200μL/L ethrel gave significantly maximum value, whereas minimum value was recorded with water-sprayed control at all sampling times in both the experiments.

At all sampling times, 80kg N/ha exhibited significantly maximum value, while minimum value was found with 0kg N/ha in both the experiments.

Regarding the interaction effect, it was observed that 200μL/L ethrel spray x 80kg N/ha proved best as compared to any other combinations (Table 86, 119).
4.2.2 Physiological characteristics

4.2.2.1 Rate of photosynthesis

Effect of ethrel spray, nitrogen and their interactions were found significant at all sampling times in both the experiments (Tables 87, 120).

At all sampling times, 200μL/L ethrel spray gave significantly maximum value and the minimum value was recorded with water-sprayed control under

Application of nitrogen at 80kg N/ha gave maximum value, while minimum value was registered with 0kg N/ha at all sampling times in both the experiments

Among interactions, 200μL/L ethrel spray x 80kg N/ha gave maximum value and minimum value was given by water-sprayed control x 0kg N/ha (Tables 87, 120)

4.2.2.2 Stomatal conductance

In Experiment 3 and 4, the effects of ethrel spray and nitrogen were significant, while their interaction effect was non-significant at all sampling times (Tables 88, 121).

At all sampling times, 200μL/L ethrel showed significantly maximum value, while the minimum value was recorded with water-sprayed control in Experiment 3 and Experiment 4

Treatment 80kg N/ha showed maximum value and the minimum value was registered with 0kg N/ha at all sampling times in both the experiments (Tables 88, 121).

4.2.2.3 Internal CO₂ concentration

Effects of ethrel spray and nitrogen were significant at all sampling times in both the experiments. The interaction effect was significant at all sampling times in Experiment 3, whereas in Experiment 4, it was significant only at 80 DAS (Tables 89, 122).
Maximum value was recorded with 200μL/L ethrel, which differed critically from other values and the minimum value was found with water-sprayed control at all sampling times in both the experiments.

At all sampling times, application of nitrogen at 80kg N/ha gave maximum value, while the minimum value was recorded with 0kg N/ha.

Regarding the interaction effect, it was observed that 200μL/L ethrel x 80kg N/ha proved best, when compared to any other combinations (Tables 89, 122).

4.2.2.4 Transpiration rate

Rate of transpiration was significantly responded towards both ethrel spray and nitrogen at all sampling times in both the experiments. However, the interaction effect was significant at all sampling times in Experiment 3, whereas in Experiment 4, it was significant only at 100 DAS (Tables 90, 123).

Maximum transpiration rate was recorded with 200μL/L ethrel spray, while minimum value was recorded in water-sprayed control at all sampling times.

At all sampling times, treatment 80kg N/ha gave significantly maximum value and minimum value was registered with 0kg N/ha in both the experiments.

Regarding the interaction effect, it was observed that 200μL/L ethrel spray x 80kg N/ha gave maximum value. Minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 90, 123).

4.2.2.5 Carboxylation efficiency

Application of ethrel spray and nitrogen resulted in significant impact on carboxylation efficiency at all sampling times in both the experiments. But the interaction effect between ethrel spray and nitrogen was significant at 100 DAS in Experiment 4, whereas in Experiment 3, the interaction effect was non-significant (Tables 91, 124).
At all sampling times, 200μL/L ethrel spray gave significantly maximum value. Minimum value found in water-sprayed control at all sampling times in both the experiments.

At all sampling times, treatment 80kg N/ha showed significantly maximum value, while the minimum value was noted with 0kg N/ha in both the experiments.

Among interactions, 200μL/L ethrel x 80kg N/ha gave significantly maximum value and minimum value was recorded with water-sprayed control x 0kg N/ha in Experiment 4 at 100 DAS (Tables 91, 124).

4.2.2.6 Photosynthetic water use efficiency

Effect of ethrel spray and application of nitrogen were significant at all sampling times in both the experiments. The interaction effect was significant only at 80 DAS in Experiment 3, and at both stages (80 and 100 DAS) in Experiment 4 (Tables 92, 125).

In Experiment 3 and 4, greatest values for photosynthetic water use efficiency were recorded with 200μL/L ethrel spray treatment at both sampling time and minimum value was noted in water-sprayed control.

Treatment 80kg N/ha showed maximum values at both sampling times in the two experiments. Significantly maximum value was given by 200μL/L ethrel x 80kg N/ha, while minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 92, 125).

4.2.2.7 Plant water use efficiency

Plant water use efficiency was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. The interaction effect between ethrel spray and nitrogen was significant at 80 DAS in Experiment 4 (Tables 93, 126).

At all sampling times, 200μL/L ethrel spray resulted in significantly maximum value and the minimum value was recorded with water-sprayed control.
Treatment 80kg N/ha gave significantly maximum value, while the minimum value was recorded with 0kg N/ha at all sampling times in both the experiments.

Among interactions, plant water use efficiency was affected by ethrel spray at 200μL/L concentration along with 80kg N/ha (Tables 93, 126).

4.2.2.8 ACC content

1-aminocyclopropane-1-carboxylic acid content was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. The interaction effect between ethrel spray and nitrogen was significant at 100 DAS in Experiment 3, and at all sampling times in Experiment 4 (Tables 94, 127). A concentration of 200μL/L ethrel showed maximum value at all sampling times. Among applied nitrogen levels, 80kg N/ha gave significantly maximum value and the minimum value was recorded with 0kg N/ha at all sampling times in both the experiments.

Regarding the interaction effect, it was observed that 200μL/L ethrel sprayed on plants grown with basal 80kg N/ha registered maximum value in both the experiments (Tables 94, 127).

4.2.2.9 ACC oxidase

Application of ethrel spray and nitrogen resulted in significant impact on ACC oxidase at all sampling times. The interaction effect was significant at 80 DAS in Experiment 3 and at 100 DAS in Experiment 4 (Table 95, 128).

Spray of 200μL/L ethrel and water spray gave significantly maximum and minimum values respectively at all sampling times in both the experiments. Application of nitrogen at 80kg N/ha resulted in maximum value and minimum value was registered with 0kg N/ha at all sampling times in both the experiments (Tables 95, 128).

Among interactions, 200μL/L ethrel x 80kg N/ha proved best, when compared to any other combinations (Tables 95, 128).
4.2.4.10 Ethylene evolution

Ethrel spray and nitrogen significantly affected the ethylene evolution at all sampling times in both the experiments. The interaction effect between these two was significant at 80 DAS in Experiment 4 (Tables 96, 129).

Ethylene evolution increased with increase in ethrel spray at both sampling times in the two experiments. Similarly, increase in nitrogen levels increased ethylene evolution. Such effect was seen in spray of 200μL/L ethrel on plants grown with 80kg N/ha, which showed significantly maximum value (Tables 96, 129).

4.2.3 Biochemical characteristics

4.2.3.1 Nitrate reductase activity

Nitrate reductase activity in leaf tissues was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. But the interaction effect between ethrel spray and nitrogen was non-significant in both the experiments (Tables 97, 130).

Spray of 200μL/L ethrel and water spray gave significantly maximum and minimum values respectively at all sampling times.

Application of nitrogen at 80kg N/ha resulted in maximum value and minimum value was registered with 0kg N/ha at all sampling times in both the experiments (Tables 97, 130).

4.2.3.2 N content

Nitrogen content in plant tissues significantly responded towards both ethrel spray and levels of nitrogen at all sampling stages in both the experiments. The interaction effect was significant at 80 DAS and 120 DAS in Experiment 3 and at 80 DAS in Experiment 4 (Tables 98, 131).

Spray of 200μL/L ethrel showed significantly maximum value at all sampling times. Among applied nitrogen levels, 80kg N/ha showed significantly maximum values at all sampling times in both the experiments.
Among interactions, 200μL/L ethrel x 80kg N/ha gave significantly maximum value and minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 98, 131).

4.2.3.3 N accumulation

Nitrogen accumulation was significantly affected by ethrel spray and nitrogen at all sampling times. The interaction effect was significant at 80 and 100 DAS in Experiment 3 and at 80 and 120 DAS in Experiment 4 (Tables 99, 132).

At all sampling times, 200μL/L ethrel spray gave significantly maximum value, while the minimum value was recorded with water-sprayed control.

Application of nitrogen at 80 and 0kg N/ha showed significantly maximum and minimum values respectively at all sampling times in both the experiments.

Regarding the interaction effect, it was observed that accumulation of nitrogen was significantly affected by 200μL/L ethrel x 80kg N/ha (Tables 99, 132).

4.2.4 Yield characteristics

4.2.4.1 Number of pods per plant

Ethrel spray and nitrogen significantly affected pod number in both the experiments. The interaction effect between ethrel spray and nitrogen was non-significant in both the experiments (Tables 100, 133).

Ethrel spray at 200μL/L concentration and water spray resulted in significantly maximum and minimum values respectively. Basal 80kg N/ha proved best for pod number in both the experiments (Tables 100, 133).

4.2.4.2 Number of seeds per pod

Number of seeds per pod was significantly influenced by ethrel spray and nitrogen in both the experiments and the interaction effect was significant in Experiment 4 (Tables 100, 133).
Individual as well as combined effect of $200\mu$L/L ethrel spray and 80kg N/ha proved superior than any other treatments (Tables 100, 133).

4.2.4.3 1000 seed weight

The seed weight was also significantly affected by ethrel spray and nitrogen in both the experiments, proving $200\mu$L/L ethrel and 80kg N/ha most effective (Tables 100, 133).

4.2.4.4 Seed yield

Seed yield of the crop was significantly affected by ethrel spray and nitrogen, but their interaction effect was non-significant in both the experiments (Tables 101, 134).

Seed yield was significantly maximum in $200\mu$L/L ethrel concentration and 80kg N/ha, while the minimum value was noted with water-sprayed control in both the experiments (Tables 101, 134).

4.2.4.5 Biological yield

Biological yield was significantly influenced by ethrel spray and nitrogen in both the experiments. But the interaction effect between these two was found significant only in Experiment 3 (Tables 101, 134).

Concentration of $200\mu$L/L ethrel spray and 80kg N/ha individually and interactively gave maximum value and the minimum value was registered with water-sprayed control (Tables 101, 134).

4.2.4.6 Harvest index

Individual and combined effect of ethrel spray and nitrogen were found significant in both the experiments (Tables 101, 134).

Significantly maximum value was recorded with $200\mu$L/L ethrel spray and 80kg N/ha and their interaction in both the experiments (Tables 101, 134).

4.2.4.7 Oil yield

Application of ethrel spray and nitrogen resulted in significant impact on oil yield. But the interaction effect was non-significant (Tables 103, 136).
Maximum value was recorded with 200μL/L ethrel and the minimum value was noted with water-sprayed control in both the experiments.

Application of nitrogen at 80kg N/ha showed maximum value, while the minimum value was recorded with 0kg N/ha (Tables 103, 136).

4.2.4.8 Seed nitrogen per plant

Effect of ethrel spray, nitrogen and their interaction were found to be significant in both the experiments (Tables 102, 135).

Among ethrel treatments, 200μL/L ethrel spray gave maximum value and the minimum was found with water-sprayed control in both the experiments.

Among applied nitrogen levels, 80kg N/ha registered highest value while control recorded significantly lowest value.

Regarding the interaction effect, it was observed that 200μL/L ethrel spray x 80kg N/ha proved best in comparison to any other combinations (Tables 102, 135).

4.2.4.9 Nitrogen harvest index

Nitrogen harvest index was non-significant for ethrel spray, applied nitrogen and their interaction (Tables 102, 135).

4.2.4.10 Nitrogen yield potential

Effect of ethrel spray application, levels of nitrogen and their interaction effect were found significant in both the experiments (Tables 102, 135).

Highest nitrogen yield potential was recorded with 200μL/L ethrel spray and the minimum value was found with water-sprayed control.

Application of nitrogen at 80kg N/ha gave maximum value and the minimum value was recorded with 0kg N/ha in both the experiments.

Among interactions, 200μL/L ethrel spray x 80kg N/ha gave significantly maximum value, while the minimum value was registered with water-sprayed control x 0kg N/ha (Tables 102, 135).
4.2.5 Quality parameters

4.2.5.1 Oil content

Effect of ethrel spray was significant, while the effect of nitrogen and interaction effect was non-significant in both the experiments (Tables 103, 136)

Ethrel spray increased oil content and 200μL/L proved most effective in both the experiments (Tables 103, 136)

4.2.5.2 Acid value

Effect of ethrel spray was significant, while nitrogen effect and their interaction effect was non-significant (Tables 104, 137)

Spray of 200μL/L ethrel showed maximum value, while the minimum was recorded with water-sprayed control (Tables 104, 137)

4.2.5.3 Iodine value

Effect of ethrel spray only was significant in both the experiments (Tables 104, 137) Maximum iodine value was recorded with 200μL/L ethrel

4.2.5.4 Saponification value

Saponification value was significantly affected by ethrel spray, while nitrogen and the interaction effect was found non-significant in both the experiments (Tables 104, 137)

Concentration of 200μL/L ethrel spray gave maximum value and the minimum value was recorded with water-sprayed control in both the experiments (Tables 104, 137)

4.2.6 Pooled analysis of Experiment 3 and 4

Pooled analysis of the data of Experiments 3 and 4 was done to evaluate the effect of ethrel spray and nitrogen application under irrigated and non-irrigated conditions (Tables 138–146) Irrigation did not significantly affect the characteristics studied The nitrogen application and ethrel spray under irrigated and non-irrigated conditions were equally effective The three-way interaction was found non-significant
4.3 Experiment 5

This experiment was conducted to confirm the effects of 200μL/L ethrel spray (reported in Experiments 1–4) on growth, physiological, biochemical, yield and quality characteristics of mustard grown under irrigated and non-irrigated conditions. For this, plants were grown with uniform basal dose of 80kg N/ha and were sprayed with either 0, 200μL/L ethrel or 1mM of silver thiosulphate (STS; a ethylene action inhibitor) at 60d after sowing (DAS; flowering stage). Growth of the plants was assessed for plant leaf area and plant dry weight, whereas other characteristics studied were similar as in Experiment 3 and Experiment 4. The details of the results are given below and summarised in Tables 147–166.

4.3.1 Growth characteristics

Spray significantly affected the plant leaf area and plant dry weight at all sampling times. The effect of spray under irrigated and non-irrigated plants for these two characteristics was similar (Tables 147, 148). Highest plant dry weight was recorded with 200μL/L ethrel spray, but the plants sprayed with silver thiosulphate (STS) showed lowest plant dry weight.

4.3.2 Physiological characteristics

Among the physiological characteristics studied, spray of 200μL/L ethrel enhanced the traits in comparison to no ethrel spray. However, spray of silver thiosulphate (1mM) reduced the effects of ethrel spray and value decreased to lower than the control.

Irrigation effect and interaction of spray with irrigation were non-significant. Similar results were observed for the photosynthetic rate, stomatal conductance, internal CO₂ concentration, carboxylation efficiency, photosynthetic water use efficiency, plant water use efficiency, 1-aminocyclopropane carboxylic acid content, ACC oxidase and ethylene evolution (Tables 149–158).
4.3.3 Biochemical characteristics

Nitrate reductase activity, nitrogen content and nitrogen accumulation were significantly affected by spray. Ethrel spray enhanced nitrogen content and accumulation in plants compared with no ethrel spray. Silver thiosulphate spray decreased these contents. Under irrigated and non-irrigated conditions, spray of ethrel was equally effective (Tables 159–161).

4.3.4 Yield characteristics

Number of pods and seeds, 1000 seed weight, seed yield, biological yield, harvest index, oil yield, seed nitrogen content per plant and nitrogen yield potential were significantly increased by 200μL/L ethrel spray. Silver thiosulphate spray confirmed the positive effect of ethylene as ethrel spray (Tables 162–164).

4.3.5 Quality characteristics

Quality assessed in terms of oil content, acid, iodine and saponification values were significantly affected by 200μL/L ethrel spray. Spray effects under irrigated conditions did not differ significantly (Tables 165–166).