



## **Effect of Irrigation Scheduling at Different Phenological Phases on Growth and Yield of Mustard (*Brassica juncea* L.) in Northern Telangana**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Optimum crop yield is not possible without the timely application and right amount of irrigation water. Since rainfall during rabi is inadequate and uncertain, scheduling of irrigation during critical stages could boost the growth, yield and water productivity of mustard. So, in order to identify critical stages of irrigation for mustard in Northern Telangana Zone, a field experiment was conducted during *rabi*, 2021-22 at Agricultural college, Jagtial to investigate the effect of irrigation scheduling at different phenological phases on growth and yield of mustard. The experiment was laid out in randomized complete block design with twelve treatments and replicated thrice. Treatments includes two irrigations each at vegetative and flowering stage (T<sub>1</sub>), two irrigations each at vegetative and siliqua development (T<sub>2</sub>), two irrigations each at flowering and siliqua development (T<sub>3</sub>), three irrigations each at vegetative, flowering and siliqua development (T<sub>4</sub>), three irrigations each at vegetative, pre-flowering and siliqua development (T<sub>5</sub>), three irrigations each at pre-flowering, siliqua initiation and siliqua development (T<sub>6</sub>), four irrigations each at vegetative, pre-flowering, flowering and siliqua development (T<sub>7</sub>), four irrigations each at vegetative, pre-flowering, flowering and siliqua initiation (T<sub>8</sub>), four irrigations each at vegetative, pre-flowering, siliqua initiation and siliqua development (T<sub>9</sub>), four irrigations each at pre-flowering, flowering, siliqua initiation and siliqua development (T<sub>10</sub>), five irrigations each at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development (T<sub>11</sub>) and scheduling of irrigation at IW/CPE ratio of 1.0 (T<sub>12</sub>). The

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results of the experiment revealed that maximum plant height (146 cm), LAI (0.89), dry matter accumulation ( $416 \text{ g m}^{-2}$ ), number of siliquae plant<sup>-1</sup> (124), number of filled seeds siliquae<sup>-1</sup> (13.65), seed yield ( $1113 \text{ kg ha}^{-1}$ ) and stover yield ( $2224 \text{ kg ha}^{-1}$ ) were recorded with five irrigations each at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development ( $T_{11}$ ). However, it was on par with irrigation scheduled at IW/CPE ratio of 1.0 ( $T_{12}$ ). While, the lowest plant height (102 cm), LAI (0.42), dry matter accumulation ( $198 \text{ g m}^{-2}$ ), number of siliquae plant<sup>-1</sup> (63), number of filled seeds siliquae<sup>-1</sup> (10.43), seed yield ( $431 \text{ kg ha}^{-1}$ ) and stover yield ( $923 \text{ kg ha}^{-1}$ ) was recorded with scheduling two irrigations at vegetative and siliqua development ( $T_2$ ).

**Keywords:** Mustard; irrigation scheduling; dry matter accumulation; seed yield.

## 1. INTRODUCTION

Oilseeds are immensely significant to the Indian economy, contributing 5% of India's GDP and 10% of the value of agricultural products. Oilseeds are India's second most important agricultural commodity after grains, accounting for roughly 13.5 percent of the country's total cropped area [1].

Mustard (*Brassica juncea* L.) belong to the family Cruciferae. The seed contains 40-45% oil and 20-25% protein [2]. The seed and oil of mustard are used as a condiment in the preparation of pickles, flavoring curries and vegetables as well as for cooking and frying purposes. Mustard oil is utilised in a variety of industrial applications, while the oil cake is used as cattle feed and manure and the green leaves are used as a vegetable and green fodder [3]. Indian mustard has recently gained popularity among farmers due to its adaptability to both irrigated and rainfed environments, as well as its appropriateness for both single and mixed cropping. It has a greater potential to boost the supply of edible oil from domestic production because it is a major winter season oilseed crop with the advantage of grown under stored soil moisture.

Optimum crop yield is not possible without the timely application and right amount of irrigation water. Since rainfall during *rabi* is inadequate and unpredictable, mustard requires supplemental irrigation for its proper growth and development otherwise; the crop may suffer from water stress and reduce ultimately the yield [4]. Scheduling of irrigation during critical stages could boost the growth, yield and water productivity of mustard. Hence the present study was conducted to determine the performance of mustard under different irrigation schedules at phenological stages.

## 2. MATERIALS AND METHODS

The current investigation was carried out at College Farm, Agricultural College, Jagtial, India, Professor Jayashankar Telangana State Agricultural University. The farm is geographically situated at  $18^\circ 50'37.0''$  N latitude and  $78^\circ 57'00.6''$  E longitude with an altitude of 243.4 m above mean sea level. The soil of the experiment field was sandy clay loam in texture. The cultivar under study was Pusa Mustard-25 sown on 27<sup>th</sup> October 2021 at a seed rate of  $5 \text{ kg ha}^{-1}$ . The applied dose of fertilizer for the cultivar i.e., 135 N, 250  $\text{P}_2\text{O}_5$  and 65  $\text{K}_2\text{O}$   $\text{kg ha}^{-1}$ . Half of the nitrogen, entire P and K are applied as basal at the time of sowing, remaining nitrogen applied just before flowering stage. While, imposing treatments on irrigation scheduling mustard crop growth period was divided into different stages i.e., Germination (0 – 9 DAS), Vegetative (10-25 DAS), Pre flowering (26 – 40 DAS), Flowering (41 – 55 DAS), Siliqua initiation (56 – 70 DAS), Siliqua development (71 – 85 DAS) and water applied in the middle of each stage, at a depth of 5 cm using water meter during each irrigation. Harvesting was done on 30<sup>th</sup> January, 2022.

Data was recorded before scheduling irrigation i.e., Vegetative stage (14 DAS), Flowering stage (45 DAS), Siliqua development (75 DAS) and at harvest from the tagged plants in each plot.

Plant height was measured from the base of the plant to the tip of the shoot before scheduling the irrigation with the help of iron scale and the average height was expressed in cm. Leaf area is measured by using the "Biovis Leaf Area meter" at various growth stages and expressed as  $\text{cm}^2 \text{ plant}^{-1}$  then LAI was calculated by dividing leaf area with unit ground area. Representative plant samples were collected from the border rows by the destructive sampling method and collected plant samples were shade dried for one day, discarding the roots, followed by oven drying at  $60^\circ\text{C}$  for 48 hours till a constant



**Map 1. Study area**

weight was attained. These dried samples are weighed and dry matter accumulation expressed in  $\text{g m}^{-2}$ . Tagged plants, which were utilised for recording the plant height were, additionally utilised for counting the number of siliquae  $\text{plant}^{-1}$  present on branches and average siliquae  $\text{plant}^{-1}$  at harvest was worked out. The mean number of seeds  $\text{siliquae}^{-1}$  was calculated from twenty randomly chosen siliquae from five tagged plants were counted out of total siliquae. 1000 seeds were counted from the weighed sample and weight of 1000 seeds was recorded as the test weight (g). Plants from the net plot area (3.6 m X 3 m) were harvested, threshed, sun dried and winnowed separately. The yield obtained from each net plot was measured in grams and later converted to  $\text{kg ha}^{-1}$ .

The data obtained analysed statistically by Analysis of Variance utilizing Randomized Block Design [5]. Statistical difference (CD) tested by applying F test at 0.05 level of probability.

### 3. RESULTS AND DISCUSSION

#### 3.1 Plant Height (cm)

Observation of experimental data revealed that there was no significant difference in plant height when irrigation scheduled at vegetative stage (Table 1). Plant height assumes significant part in the capture of light and sun-oriented radiation. Plant height is determined by cell division, cell

enlargement and cell differentiation all of which requires sufficient water.

Plant height at flowering stage ranges from (56 to 85cm). Treatment with 5 irrigations each at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development ( $T_{11}$ ) had the highest plant height (85 cm) and it was on par with treatments  $T_5$  to  $T_{12}$ . While, the lowest plant height (56 cm) recorded in treatments with two irrigations each at flowering and siliqua development ( $T_3$ ) in turn, it was on par with treatments provided two irrigations at vegetative and siliqua development ( $T_3$ ) and two irrigations at vegetative and flowering stage ( $T_1$ ).

Significantly higher plant height (140 cm) at siliqua development was observed in treatments when irrigation imposed at IW/CPE ratio of 1.0 which was on par with treatment ( $T_8$  to  $T_{11}$ ). The lower plant height (97 cm) was recorded in treatments provided with two irrigations at vegetative and siliqua development ( $T_2$ ) due to moisture stress during flowering stage and siliqua stage which was on par with treatment ( $T_3$ ) when irrigated each at flowering and siliqua development (107 cm).

At harvest the highest plant height was seen in treatment with an IW/CPE ratio of 1.0 ( $T_{12}$ ) in turn, it was on par with treatments ( $T_8$  to  $T_{11}$ ). While, the treatment with two irrigations each at vegetative and siliqua development ( $T_2$ ) had the

lowest plant height (102 cm) which was on par with treatment (T<sub>3</sub>) when irrigated each at flowering and siliqua development (Table 1).

The increased plant height with increasing number of irrigations might be due to increased water availability has caused progressive tissue initiation and cell expansion which may aided in nutrient mobilization and thereby making plant physiologically more active. Similar findings were reported with Yadav et al. [6], Mila et al. [7], Verma et al. [8], Chaudari et al. [9] and Rathore et al. [10].

### 3.2 Leaf Area Index

Leaf area index increased progressively throughout different stages of the crop growth up to flowering, after which it began to decline. Mustard LAI growth trend might be linked to the plant's regular typical growth pattern, and the increase in LAI could be the consequence of the cumulative effect of increased leaf number and leaf growth as the plant ages. The decline in LAI was caused by the drying and fall of leaves when the senescence period began. Irrigation scheduled during vegetative has no significant different among treatments. It is evident from the data presented in Table 2.

When irrigation was set at an IW/CPE ratio of 1.0, a higher LAI (3.67) was observed during the flowering stage. However, it is at par with T<sub>5</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>9</sub>, and T<sub>11</sub>. Increased water availability at critical stages resulted in better nutrient uptake, cell growth and division, higher photosynthetic activity and thus resulted in superior growth indices. These results were in line with Puppala et al. [11].

While, two irrigations each at flowering and siliqua development (T<sub>3</sub>) results in much lower LAI (2.01) which was on par with treatments (T<sub>2</sub>) with two irrigations each at vegetative and flowering stages (2.33). Water shortages have notably repressed leaf development through decrease of relative leaf turgidity. Similar results were reported with Verma et al. [6] and Tamboli et al. [12].

### 3.3 Dry Matter Accumulation (g m<sup>-2</sup>)

After respiration and anabolic processes, photosynthates accumulate as dry matter. A perusal of data summarized in Table 3, showed a consistent increase in dry matter accumulation up to siliqua development and then at slower rate

till harvest. Data collected on dry matter accumulation at vegetative stage had no significant difference between treatments.

At flowering stage, irrigation scheduling at 1.0 IW/CPE (T<sub>12</sub>) resulted in significantly higher dry matter accumulation (46.23 g m<sup>-2</sup>), which was on par with treatments (T<sub>5</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>9</sub>, T<sub>11</sub>) with 43.67, 42.38, 43.13, 42.67, 42.45 g m<sup>-2</sup> respectively. Treatment with two irrigations at flowering and siliqua development (T<sub>3</sub>) had lower dry matter accumulation (25.33 g m<sup>-2</sup>) due to lack of water availability during vegetative stage, which resulted in protoplasm dehydration, which decreased turgor potential and turgor-driven physiological processes and it was on par with the treatment (T<sub>3</sub>) provided two irrigations at vegetative and siliqua development (29.33 g m<sup>-2</sup>).

Treatments with irrigation imposed at an IW/CPE ratio of 1.0 had significantly higher dry matter accumulation (336.27 g m<sup>-2</sup>) at siliqua development, which was on par with treatment (T<sub>11</sub>) provided with five irrigations each at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development (333.33 g m<sup>-2</sup>). While, lower dry matter accumulation (158.67 g m<sup>-2</sup>) was attained in treatments provided with two irrigations at vegetative and siliqua development (T<sub>2</sub>) due to moisture stress throughout flowering stage and siliqua initiation stage.

At harvest, dry matter accumulation ranges from (420.33 to 198.33g m<sup>-2</sup>), irrigation scheduling at IW/CPE ratio of 1.0 (T<sub>12</sub>) results in significantly higher dry matter accumulation (420.33 g m<sup>-2</sup>) and it was on par with treatments (T<sub>11</sub>) with five irrigations each at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development (416.67 g m<sup>-2</sup>). It could be due to adequate and appropriate water supply to plants, which increased cell turgidity and cell enlargement as well as meristematic activity resulted in increased photosynthesis and bio mass accumulation. These results were in agreement with experimental findings of Puppala et al. (2019). While, the lowest dry matter (198.33 g m<sup>-2</sup>) was observed in treatment that received two irrigation each at vegetative and siliqua development (T<sub>2</sub>) due to devoid of water during flowering stage and siliqua initiation stage results in dehydration of protoplasm which results in decreased the turgor potential and turgor driven physiological processes such as cell division and cell elongation which affect the plant growth and eventually the total dry matter

**Table 1. Plant height(cm) of mustard as influenced by irrigation scheduling at different phenophases during *rabi*, 2021-22**

| Treatments  | Plant height (cm) |           |                     |         |
|---|-------------------|-----------|---------------------|---------|
|   | Vegetative        | Flowering | Siliqua development | Harvest |
| T <sub>1</sub> Two irrigations at Vegetative and Flowering stage  | 5.51              | 64.61     | 114.00              | 119.70  |
| T <sub>2</sub> Two irrigations at Vegetative and Siliqua development  | 6.47              | 64.67     | 97.93               | 102.72  |
| T <sub>3</sub> Two irrigations at Flowering and Siliqua development   | 6.69              | 56.67     | 107.60              | 112.98  |
| T <sub>4</sub> Three irrigations at Vegetative, Flowering and Siliqua development                                     | 5.77              | 73.94     | 117.67              | 123.55  |
| T <sub>5</sub> Three irrigations at Vegetative, Pre-flowering and Siliqua development                                 | 5.92              | 87.77     | 122.87              | 129.01  |
| T <sub>6</sub> Three irrigations at Pre-flowering, Siliqua initiation and Siliqua development                         | 6.70              | 84.26     | 124.60              | 130.83  |
| T <sub>7</sub> Four irrigations at Vegetative, Pre-flowering, Flowering and Siliqua development                       | 5.57              | 86.67     | 128.07              | 134.47  |
| T <sub>8</sub> Four irrigations at Vegetative, Pre-flowering, Flowering and Siliqua initiation                        | 6.97              | 83.27     | 131.60              | 138.16  |
| T <sub>9</sub> Four irrigations at Vegetative, Pre-flowering, Siliqua initiation and Siliqua development              | 6.45              | 85.29     | 131.33              | 137.90  |
| T <sub>10</sub> Four irrigations at Pre-flowering, Flowering, Siliqua initiation and Siliqua development              | 6.43              | 77.69     | 136.40              | 143.13  |
| T <sub>11</sub> Five irrigations at Vegetative, Pre-flowering, Flowering, Siliqua initiation and Siliqua development. | 6.50              | 85.92     | 139.80              | 146.79  |
| T <sub>12</sub> Scheduling of irrigation at IW/CPE ratio of 1.0   | 5.85              | 84.33     | 140.67              | 147.70  |
| SEm±  | 0.555             | 2.991     | 3.831               | 3.522   |
| CD @ 5%   | 1.612             | 8.828     | 11.309              | 10.396  |
| CV (%)  | 15.408            | 6.647     | 5.335               | 4.672   |

**Table 2. LAI of mustard as influenced by irrigation scheduling at different phenophases during *rabi*, 2021-22**

| Treatments  | Leaf area Index (LAI) |           |                     |         |
|---|-----------------------|-----------|---------------------|---------|
|   | Vegetative            | Flowering | Siliqua development | Harvest |
| T <sub>1</sub> Two irrigations at Vegetative and Flowering stage  | 0.95                  | 2.43      | 1.40                | 0.48    |
| T <sub>2</sub> Two irrigations at Vegetative and Siliqua development  | 0.92                  | 2.33      | 1.13                | 0.42    |
| T <sub>3</sub> Two irrigations at Flowering and Siliqua development   | 0.88                  | 2.01      | 1.28                | 0.52    |
| T <sub>4</sub> Three irrigations at Vegetative, Flowering and Siliqua development                                     | 0.79                  | 2.54      | 1.57                | 0.59    |
| T <sub>5</sub> Three irrigations at Vegetative, Pre-flowering and Siliqua development                                 | 0.97                  | 3.46      | 1.91                | 0.71    |
| T <sub>6</sub> Three irrigations at Pre-flowering, Siliqua initiation and Siliqua development                         | 0.94                  | 2.80      | 1.98                | 0.74    |
| T <sub>7</sub> Four irrigations at Vegetative, Pre-flowering, Flowering and Siliqua development                       | 0.93                  | 3.36      | 1.94                | 0.72    |
| T <sub>8</sub> Four irrigations at Vegetative, Pre-flowering, Flowering and Siliqua initiation                        | 0.89                  | 3.42      | 2.16                | 0.73    |
| T <sub>9</sub> Four irrigations at Vegetative, Pre-flowering, Siliqua initiation and Siliqua development              | 0.86                  | 3.38      | 1.97                | 0.80    |
| T <sub>10</sub> Four irrigations at Pre-flowering, Flowering, Siliqua initiation and Siliqua development              | 0.91                  | 2.95      | 2.21                | 0.83    |
| T <sub>11</sub> Five irrigations at Vegetative, Pre-flowering, Flowering, Siliqua initiation and Siliqua development. | 0.87                  | 3.36      | 2.38                | 0.89    |
| T <sub>12</sub> Scheduling of irrigation at IW/CPE ratio of 1.0   | 0.90                  | 3.67      | 2.40                | 0.89    |
| SEm±  | 0.056                 | 0.135     | 0.042               | 0.016   |
| CD @ 5%   | 0.163                 | 0.397     | 0.124               | 0.046   |
| CV (%)  | 10.776                | 7.838     | 3.901               | 3.899   |

**Table 3. Dry matter production (g m<sup>-2</sup>) of mustard as influenced by irrigation scheduling at different phenophases during *rabi*, 2021-22**

| Treatments  | Dry matter production (g m <sup>-2</sup> ) |           |                     |         |
|---|--|-----------|---------------------|---------|
|   | Vegetative                                 | Flowering | Silique development | harvest |
| T <sub>1</sub> Two irrigations at Vegetative and Flowering stage  | 5.77                                       | 30.67     | 196.53              | 224.33  |
| T <sub>2</sub> Two irrigations at Vegetative and Silique development  | 5.60                                       | 29.33     | 158.67              | 198.33  |
| T <sub>3</sub> Two irrigations at Flowering and Silique development   | 5.35                                       | 25.33     | 179.47              | 245.67  |
| T <sub>4</sub> Three irrigations at Vegetative, Flowering and Silique development                                     | 4.82                                       | 32.00     | 220.36              | 275.45  |
| T <sub>5</sub> Three irrigations at Vegetative, Pre-flowering and Silique development                                 | 5.87                                       | 43.67     | 267.73              | 334.67  |
| T <sub>6</sub> Three irrigations at Pre-flowering, Silique initiation and Silique development                         | 5.73                                       | 35.33     | 277.33              | 346.67  |
| T <sub>7</sub> Four irrigations at Vegetative, Pre-flowering, Flowering and Silique development                       | 5.63                                       | 42.38     | 272.27              | 340.33  |
| T <sub>8</sub> Four irrigations at Vegetative, Pre-flowering, Flowering and Silique initiation                        | 5.43                                       | 43.13     | 302.51              | 345.33  |
| T <sub>9</sub> Four irrigations at Vegetative, Pre-flowering, Silique initiation and Silique development              | 5.25                                       | 42.67     | 276.27              | 378.13  |
| T <sub>10</sub> Four irrigations at Pre-flowering, Flowering, Silique initiation and Silique development              | 5.52                                       | 37.20     | 310.40              | 388.00  |
| T <sub>11</sub> Five irrigations at Vegetative, Pre-flowering, Flowering, Silique initiation and Silique development. | 5.29                                       | 42.45     | 333.33              | 416.67  |
| T <sub>12</sub> Scheduling of irrigation at IW/CPE ratio of 1.0   | 5.45                                       | 46.23     | 336.27              | 420.33  |
| SEm±  | 0.341                                      | 1.698     | 5.876               | 7.346   |
| CD @ 5%   | 0.990                                      | 5.014     | 17.344              | 21.683  |
| CV (%)  | 10.776                                     | 7.838     | 3.900               | 3.901   |

**Table 4. Yield attributes of mustard as influenced by irrigation scheduling at different phenophases during *rabi*, 2021-22**

| Treatments  | Number of Siliqua plant <sup>-1</sup> | Number of filled seeds siliquae <sup>-1</sup> | Test weight(g) |
|---|---------------------------------------|---|----------------|
| T <sub>1</sub> Two irrigations at Vegetative and Flowering stage  | 75.33                                 | 10.87   | 4.76           |
| T <sub>2</sub> Two irrigations at Vegetative and Siliqua development  | 63.00                                 | 10.43   | 4.46           |
| T <sub>3</sub> Two irrigations at Flowering and Siliqua development   | 84.07                                 | 11.24   | 4.92           |
| T <sub>4</sub> Three irrigations at Vegetative, Flowering and Siliqua development                                     | 88.67                                 | 11.47   | 5.21           |
| T <sub>5</sub> Three irrigations at Vegetative, Pre-flowering and Siliqua development                                 | 101.00                                | 11.97   | 5.17           |
| T <sub>6</sub> Three irrigations at Pre-flowering, Siliqua initiation and Siliqua development                         | 110.33                                | 12.18   | 5.49           |
| T <sub>7</sub> Four irrigations at Vegetative, Pre-flowering, Flowering and Siliqua development                       | 94.40                                 | 11.51   | 5.24           |
| T <sub>8</sub> Four irrigations at Vegetative, Pre-flowering, Flowering and Siliqua initiation                        | 98.67                                 | 11.59   | 5.44           |
| T <sub>9</sub> Four irrigations at Vegetative, Pre-flowering, Siliqua initiation and Siliqua development              | 112.67                                | 12.18   | 5.55           |
| T <sub>10</sub> Four irrigations at Pre-flowering, Flowering, Siliqua initiation and Siliqua development              | 116.27                                | 12.28   | 5.64           |
| T <sub>11</sub> Five irrigations at Vegetative, Pre-flowering, Flowering, Siliqua initiation and Siliqua development. | 124.80                                | 13.65   | 5.65           |
| T <sub>12</sub> Scheduling of irrigation at IW/CPE ratio of 1.0   | 135.67                                | 13.88   | 5.54           |
| SEm±  | 4.168                                 | 0.270   | 0.238          |
| CD @ 5%   | 12.303                                | 0.796   | 0.702          |
| CV (%)  | 7.190                                 | 3.913   | 7.834          |



**Table 5. Yield (kg ha<sup>-1</sup>) of mustard as influenced by irrigation scheduling at different phenophases during *rabi*, 2021-22**

| <b>Treatments</b> |   | <b>Seed yield (kg ha<sup>-1</sup>)</b> | <b>Stover yield (kg ha<sup>-1</sup>)</b> |
|-------------------|---|--|--|
| T <sub>1</sub>    | Two irrigations at Vegetative and Flowering stage   | 546                                    | 1113                                     |
| T <sub>2</sub>    | Two irrigations at Vegetative and Siliqua development   | 431                                    | 923                                      |
| T <sub>3</sub>    | Two irrigations at Flowering and Siliqua development  | 582                                    | 1161                                     |
| T <sub>4</sub>    | Three irrigations at Vegetative, Flowering and Siliqua development                                    | 618                                    | 1300                                     |
| T <sub>5</sub>    | Three irrigations at Vegetative, Pre-flowering and Siliqua development                                | 653                                    | 1297                                     |
| T <sub>6</sub>    | Three irrigations at Pre-flowering, Siliqua initiation and Siliqua development                        | 831                                    | 1591                                     |
| T <sub>7</sub>    | Four irrigations at Vegetative, Pre-flowering, Flowering and Siliqua development                      | 728                                    | 1488                                     |
| T <sub>8</sub>    | Four irrigations at Vegetative, Pre-flowering, Flowering and Siliqua initiation                       | 765                                    | 1577                                     |
| T <sub>9</sub>    | Four irrigations at Vegetative, Pre-flowering, Siliqua initiation and Siliqua development             | 902                                    | 1907                                     |
| T <sub>10</sub>   | Four irrigations at Pre-flowering, Flowering, Siliqua initiation and Siliqua development              | 968                                    | 1945                                     |
| T <sub>11</sub>   | Five irrigations at Vegetative, Pre-flowering, Flowering, Siliqua initiation and Siliqua development. | 1113                                   | 2224                                     |
| T <sub>12</sub>   | Scheduling of irrigation at IW/CPE ratio of 1.0   | 1143                                   | 2372                                     |
| SEm±              |   | 33                                     | 59                                       |
| CD @ 5%           |   | 97                                     | 175                                      |
| CV (%)            |   | 7.4                                    | 6.5                                      |

accumulation (Tyagi and Upadhyay [13]. Similar results were reported with Piri et al. [14], Verma et al. [15] and Rana et al. [16].

### 3.4 Yield Attributes

Number of irrigations at different phenophases had a considerable impact on yield attributes of mustard (Table 4). Among the different irrigation scheduling treatments, highest number of siliqua plant<sup>-1</sup> (135.67), number of seeds siliquae<sup>-1</sup> (13.88) in mustard were recorded with irrigation scheduled at 1.0 IW/CPE which in turn, on par with treatment (T<sub>11</sub>) provided with 5 irrigations each at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development stages (124.80 and 13.65 respectively). It is due to frequent irrigation application reduced water stress in the soils and generated a favourable environment for the plants in respect of water availability, providing congenial conditions for the growth and development of higher number of siliquae plant<sup>-1</sup> and number of filled seeds siliqua<sup>-1</sup>.

However, the highest test weight (5.65 g) was recorded with treatment (T<sub>11</sub>) with five irrigations each at at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development stages. This might be due to higher photosynthesis and translocation of assimilates towards reproductive structures owing to adequate soil moisture. While, treatment (T<sub>2</sub>) provided with two irrigations each at vegetative and siliqua development stage had lowest number of siliqua plant<sup>-1</sup> (63.00), number of filled seeds siliquae<sup>-1</sup>(10.43) and test weight (4.46 g) which was on par with treatment (T<sub>1</sub>) with two irrigations each at vegetative and siliqua development. These findings were in accordance with Shivran et al. [17], Yadav et al. [18], Tripathi et al. [19], Ray et al. [20] and Nautilya et al. [21].

### 3.5 Seed Yield (Kg ha<sup>-1</sup>)

Yield is the result of coordinated interplay of growth characters and yield attributes. Significantly the highest seed yield (1143 kg ha<sup>-1</sup>) was obtained with irrigation scheduled at IW/CPE ratio of 1.0 (T<sub>12</sub>) which was on par with treatment (T<sub>11</sub>) that received five irrigations each at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development stages (1113 kg ha<sup>-1</sup>) and the lowest seed yield (431 kg ha<sup>-1</sup>) when irrigated twice each at vegetative and siliqua development. Data pertaining to seed and stover yield represented in Table 5.

Seed yield is the function of dry matter and yield attributes of plant which have increased 61.2 % as the number of irrigations increased from two to five irrigations. This could be because it also be linked to increased photosynthates and photosynthetic translocation to reproductive structures in the mustard crop's rhizosphere due to adequate soil moisture. Adequate supply of moisture in soil helps in proper utilization of plant nutrients, resulting in proper growth and high yield. Whereas, irrigation imposed each at vegetative and siliqua development produced the lowest plant height, filled siliqua plant<sup>-1</sup>, number of seed siliqua<sup>-1</sup> and 1000- seed weight due to devoid of moisture throughout the flowering and siliqua initiation stage. These findings were in agreement with Hossain et al. [22], Dadich et al. [23], Singh and Thenua [24] and Shivran et al. [25].

### 3.6 Stover Yield (Kg ha<sup>-1</sup>)

The stover yield grew substantially as number of irrigations increased from two to five irrigations. This rise was attributed to increased moisture availability, which resulted in a better nutritional environment during critical growth phases of the crop, resulting in improved vegetative growth. Irrigation with an IW/CPE ratio of 1.0 (T<sub>12</sub>) resulted in the maximum stover output (2372 kg ha<sup>-1</sup>) which was a par with treatment (T<sub>11</sub>) in which imposed five irrigations each at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development stage (2224 kg ha<sup>-1</sup>). Lower stover yield noticed in treatment (T<sub>2</sub>) when irrigation scheduled each at vegetative and siliqua development. It might be due to moisture stress during flowering period.

## 4. CONCLUSIONS

The present investigation found that deficit and optimum irrigation schedules had a substantial impact on growth, yield attributes and yield of mustard. It is concluded that irrigation scheduled with five irrigation each at vegetative, pre-flowering, flowering, siliqua initiation and siliqua development results in highest seed output (1113 kg ha<sup>-1</sup>). Further, under limited water supply, schedule four irrigations each during pre-flowering, flowering, siliqua initiation, and siliqua development (968 kg ha<sup>-1</sup>), if three irrigations are available schedule at pre-flowering, siliqua initiation and siliqua development (831 kg ha<sup>-1</sup>) for higher growth and yield of mustard in Northern Telangana Zone.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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