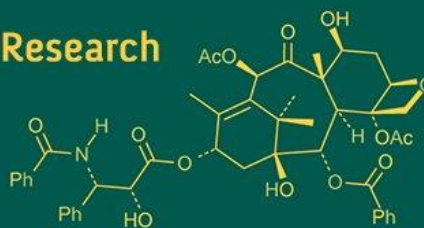


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## Effect of plant growth retardants on morpho-physiological, biochemical and yield parameters of sorghum (*Sorghum bicolor* L.)

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**Abstract**

A field experiment was conducted at the Agricultural Research Station, Bheemaranagudi, during the Rabi season of 2022-23 to evaluate the effects of plant growth retardants on morpho-physiological, biochemical traits and yield of sorghum (*Sorghum bicolor* L.). The experiment was laid out in a randomized complete block design with three replications, comprising eleven treatments including control, water spray, mepiquat chloride (1000, 1500, and 2000 ppm), chlormequat chloride (1000, 1500, and 2000 ppm) and ethephon (200, 400, and 600 ppm) applied as foliar sprays at 35 days after sowing (DAS). The results revealed that growth retardant treatments significantly reduced plant height and enhanced total dry matter production, leaf area, leaf area index (LAI), photosynthetic rate, transpiration rate, total chlorophyll content and seed yield compared to the control. Among the treatments, foliar application of mepiquat chloride @ 2000 ppm (T<sub>5</sub>) recorded significantly higher values for total dry matter (195.6 g plant<sup>-1</sup>), leaf area (3212.2 cm<sup>2</sup> plant<sup>-1</sup>), LAI (4.76), photosynthetic rate (35.65 μmol CO<sub>2</sub> m<sup>-2</sup> s<sup>-1</sup>), transpiration rate (3.95 mmol H<sub>2</sub>O m<sup>-2</sup> s<sup>-1</sup>), chlorophyll content (3.02 mg g<sup>-1</sup> fresh weight) and seed yield (1724.9 kg ha<sup>-1</sup>), along with reduced plant height (178.30 cm). Chlormequat chloride @ 1500 ppm (T<sub>7</sub>) was the next superior treatment, recording higher values than other treatments but remaining inferior to T<sub>5</sub>. The study concludes that foliar application of mepiquat chloride @ 2000 ppm at 35 DAS is effective in enhancing growth, physiological efficiency, and productivity in sorghum.

**Keywords:** Sorghum, plant growth retardants, Mepiquat chloride, Chlormequat chloride Morpho-physiological traits, photosynthetic rate, chlorophyll content, seed yield

**Introduction**

Sorghum (*Sorghum bicolor* L. Moench) is an important cereal crop cultivated predominantly by resource-poor, small, and marginal farmers in semi-arid regions. In India, sorghum grown during the rainy (kharif) season is utilized for both human consumption and livestock feed, whereas the post-rainy (rabi) season produce is primarily used for human consumption. Thus, sorghum plays a vital role in sustaining both human and livestock populations. During 2021-22, sorghum in India was cultivated over an area of 4.8 million hectares with a production of 4.6 million tonnes and an average productivity of 1000 kg ha<sup>-1</sup> (Anon., 2022) [2]. It is one of the most important cereal crops grown in semi-arid and arid regions due to its inherent tolerance to drought and high temperature (Reddy *et al.*, 2010) [19]. It serves as a staple food, fodder, and industrial raw material, contributing significantly to food and nutritional security (Taylor, 2003) [23]. However, achieving higher productivity in sorghum remains a challenge due to excessive vegetative growth, lodging, and suboptimal partitioning of assimilates under varying environmental conditions.

Plant growth retardants (PGRs) play a crucial role in modifying plant architecture by inhibiting gibberellin biosynthesis, thereby reducing plant height and improving canopy structure (Davies, 2010) [4]. Such modifications enhance light interception, photosynthetic efficiency, and assimilate partitioning towards reproductive organs, ultimately improving yield (Taiz *et al.*, 2015) [22]. Among the commonly used growth retardants, mepiquat chloride, chlormequat chloride (CCC), and ethephon have been reported to influence morpho-physiological and biochemical processes in crops (Rademacher, 2000) [18].

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Mepiquat chloride restricts excessive vegetative growth and promotes efficient utilization of assimilates, whereas chlormequat chloride regulates cell elongation and enhances stem strength, thereby reducing lodging. Ethephon, an ethylene-releasing compound, influences various physiological processes including senescence, source-sink relationships, and stress responses (Abeles *et al.*, 1992) [1]. These growth regulators also affect key physiological parameters such as photosynthetic rate, transpiration rate, and chlorophyll content, which are directly associated with crop productivity (Ashraf *et al.*, 2006) [3].

Despite the documented benefits of plant growth retardants in several crops, limited information is available regarding their comparative effectiveness on morpho-physiological, biochemical traits, and yield performance in sorghum under field conditions. Therefore, the present investigation was undertaken to evaluate the effects of different plant growth retardants on growth, physiological and biochemical parameters, and their consequent influence on yield in sorghum.

## Materials and Methods

A field experiment was conducted during the Rabi season of 2022-23 at the Agricultural Research Station, Bheemaranagudi, University of Agricultural Sciences, Raichur, Karnataka. The experimental site is located in the Northern Dry Zone of Karnataka and is characterized by a semi-arid climate. The soil of the experimental field was medium deep black with moderate fertility status.

The experiment was laid out in a randomized complete block design (RCBD) with three replications, comprising eleven treatments. The treatments included control (no spray), water spray, mepiquat chloride at 1000, 1500, and 2000 ppm, chlormequat chloride at 1000, 1500, and 2000 ppm, and ethephon at 200, 400, and 600 ppm. The recommended package of practices for sorghum cultivation was followed uniformly for all treatments.

The growth retardants were applied as foliar sprays at 35 days after sowing (DAS) using a hand sprayer with uniform spray volume. Observations on morphological parameters such as plant height (cm), total dry matter production ( $\text{g plant}^{-1}$ ), total leaf area ( $\text{cm}^2 \text{ plant}^{-1}$ ), and leaf area index (LAI) were recorded at appropriate growth stages following standard procedures. Physiological parameters including photosynthetic rate ( $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ ) and transpiration rate ( $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ ) were measured using a portable photosynthesis system. Total chlorophyll content ( $\text{mg g}^{-1}$  fresh weight) was estimated using standard biochemical methods.

At harvest, seed yield ( $\text{kg ha}^{-1}$ ) was recorded from each treatment plot and computed on hectare basis. The data obtained from various observations were statistically analysed using analysis of variance (ANOVA) as described by Panse and Sukhatme (1967). Treatment means were compared using the appropriate critical difference (CD) at 5 percent level of significance.

## Results and Discussion

The data on morphological parameters of sorghum are presented in Table 1. The control ( $T_1$ ) recorded significantly higher plant height (258.60 cm) compared to all other treatments. Among the treatments, foliar application of mepiquat chloride @ 2000 ppm ( $T_5$ ) recorded the lowest plant height (178.30 cm), followed by chlormequat chloride

@ 1500 ppm ( $T_7$ ) with 190.40 cm. The reduction in plant height due to growth retardants may be attributed to inhibition of gibberellin biosynthesis, which restricts cell elongation. Similar findings were reported by Kamran *et al.* (2018) [9] in maize and Kashid *et al.* (2010) [11] in sunflower. Growth retardants such as cycocel and mepiquat chloride act as anti-gibberellin agents by blocking the conversion of geranyl pyrophosphate to copalyl pyrophosphate, an early step in gibberellin synthesis (Moore, 1980) [14].

Total leaf area was significantly higher in  $T_5$  ( $2325 \text{ cm}^2 \text{ plant}^{-1}$ ) and the lowest was recorded in control ( $T_1$ ) ( $1655 \text{ cm}^2 \text{ plant}^{-1}$ ). Increased leaf area enhances photosynthetic capacity, thereby contributing to higher productivity. Leaf area increased up to 90 DAS and declined thereafter due to senescence and leaf shedding. Similar results were reported by Garg *et al.* (2006) [6] in cluster bean and Phulekar *et al.* (1998) [15] in groundnut.

Total dry matter production was significantly higher in  $T_5$  ( $195.64 \text{ g plant}^{-1}$ ), followed by  $T_7$  ( $186.35 \text{ g plant}^{-1}$ ), while the lowest was recorded in control ( $122.84 \text{ g plant}^{-1}$ ). Increased dry matter accumulation under growth retardant treatments may be due to enhanced photosynthetic efficiency and better translocation of assimilates towards reproductive organs. Reduced plant height and increased stem thickness also contribute to higher dry matter accumulation. These findings are in agreement with Gangadhara *et al.* (2022) [5], Kashid *et al.* (2010) [11], and Phulekar *et al.* (1998) [15].

Leaf area index (LAI) was significantly higher in  $T_5$  (3.44) and lowest in control (2.45). Enhanced LAI may be attributed to increased branching and efficient assimilate translocation. Similar results were reported by Srivastava and Tiwari (1981) [20] and Islam and Jahan (2016) [7].

Seed yield was significantly higher in  $T_5$  ( $1724.9 \text{ kg ha}^{-1}$ ), representing a 42.6 percent increase over control, followed by  $T_7$  ( $1671.4 \text{ kg ha}^{-1}$ ), while the lowest yield was recorded in control ( $1354.5 \text{ kg ha}^{-1}$ ). The increase in yield may be due to improved morpho-physiological efficiency and better assimilate partitioning. Similar findings were reported by Kamran *et al.* (2018) [9], Techapinyawat *et al.* (1995) [24], Kashid *et al.* (2010) [11], Kalyankar *et al.* (2007) [8], and Pourmohammad *et al.* (2014) [16].

The data on physiological and biochemical parameters are presented in Table 2. Photosynthetic rate was significantly higher in  $T_5$  ( $35.65 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ ), followed by  $T_7$  ( $33.54 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ ), while the lowest was recorded in control ( $21.88 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ ). Increased photosynthetic rate may be attributed to higher chlorophyll content and LAI. Similar results were reported by Rajesh *et al.* (2014) [17] and Karuppusamy *et al.* (2021) [10].

Transpiration rate was significantly higher in  $T_5$  ( $3.95 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ ) followed by  $T_7$  ( $3.82 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ ), while the lowest was observed in control ( $3.18 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ ). The increase in transpiration rate might be due to improved stomatal conductance. These results are in agreement with Liu *et al.* (2016) [13].

Total chlorophyll content was significantly higher in  $T_5$  ( $2.77 \text{ mg g}^{-1}$  fresh weight), followed by  $T_7$  ( $2.66 \text{ mg g}^{-1}$ ), whereas the lowest was recorded in control ( $1.93 \text{ mg g}^{-1}$ ). Increased chlorophyll content may be due to enhanced synthesis and delayed degradation of chlorophyll pigments. Growth retardants improve source-sink relationships and prolong chlorophyll synthesis (Stoddart, 1965) [21]. Similar findings were reported by Kashid *et al.* (2010) [11], Wasnik

and Bagga (1996) [26], and Kulkarni *et al.* (1995) [12]. Overall, foliar application of mepiquat chloride @ 2000 ppm (T<sub>5</sub>) was found to be the most effective treatment in

improving morpho-physiological, biochemical parameters, and yield in sorghum, followed by chlormequat chloride @ 1500 ppm (T<sub>7</sub>).

**Table 1:** Influence of plant growth retardants on morphological parameters at 90 DAS and yield in sorghum

| Treatments                                      | Plant height (cm) | Total dry matter (g plant <sup>-1</sup> ) | Total leaf area (dm <sup>2</sup> plant <sup>-1</sup> ) | Leaf area index (LAI) | Yield per hectare (kg ha <sup>-1</sup> ) |
|-------------------------------------------------|-------------------|-------------------------------------------|--------------------------------------------------------|-----------------------|------------------------------------------|
| T <sub>1</sub> -Control                         | 258.60            | 122.8                                     | 2383.5                                                 | 3.53                  | 1354.5                                   |
| T <sub>2</sub> -Water spray                     | 250.60            | 125.6                                     | 2459.7                                                 | 3.64                  | 1388.4                                   |
| T <sub>3</sub> -Mepiquat chloride @ 1000 ppm    | 212.80            | 171.7                                     | 2815.1                                                 | 4.17                  | 1622.6                                   |
| T <sub>4</sub> -Mepiquat chloride @ 1500 ppm    | 205.40            | 179.0                                     | 2959.4                                                 | 4.38                  | 1645.7                                   |
| T <sub>5</sub> -Mepiquat chloride @ 2000 ppm    | 178.30            | 195.6                                     | 3212.2                                                 | 4.76                  | 1724.9                                   |
| T <sub>6</sub> -Chlormequat chloride @ 1000 ppm | 219.50            | 163.9                                     | 2815.9                                                 | 4.17                  | 1572.5                                   |
| T <sub>7</sub> -Chlormequat chloride @ 1500 ppm | 190.40            | 186.3                                     | 3125.5                                                 | 4.63                  | 1671.4                                   |
| T <sub>8</sub> -Chlormequat chloride @ 2000 ppm | 234.70            | 154.8                                     | 2613.8                                                 | 3.87                  | 1521.1                                   |
| T <sub>9</sub> -Ethephon @ 200 ppm              | 244.60            | 143.5                                     | 2599.5                                                 | 3.85                  | 1459.2                                   |
| T <sub>10</sub> -Ethephon @ 400 ppm             | 240.30            | 148.3                                     | 2586.4                                                 | 3.83                  | 1482.1                                   |
| T <sub>11</sub> -Ethephon @ 600 ppm             | 225.70            | 159.4                                     | 2715.6                                                 | 4.02                  | 1540.2                                   |
| Mean                                            | 223.7             | 159.2                                     | 2752.6                                                 | 4.07                  | 1543.8                                   |
| S.Em (±)                                        | 2.07              | 1.78                                      | 28.36                                                  | 0.04                  | 15.1                                     |
| C.D at 5%                                       | 6.12              | 5.26                                      | 84.66                                                  | 0.12                  | 44.7                                     |

**Table 2:** Influence of plant growth retardants on biophysical, biochemical parameters and yield in sorghum.

| Treatments                                      | Photosynthetic rate (μ mol CO <sub>2</sub> m <sup>-2</sup> s <sup>-1</sup> ) | Transpiration rate (m mol H <sub>2</sub> O m <sup>-2</sup> s <sup>-1</sup> ) | Total chlorophyll content (mg g <sup>-1</sup> fr. wt.) | Yield per hectare (kg ha <sup>-1</sup> ) |
|-------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------|------------------------------------------|
| T <sub>1</sub> -Control                         | 21.88                                                                        | 3.18                                                                         | 2.27                                                   | 1354.5                                   |
| T <sub>2</sub> -Water spray                     | 22.76                                                                        | 3.22                                                                         | 2.35                                                   | 1388.4                                   |
| T <sub>3</sub> -Mepiquat chloride @ 1000 ppm    | 30.87                                                                        | 3.69                                                                         | 2.74                                                   | 1622.6                                   |
| T <sub>4</sub> -Mepiquat chloride @ 1500 ppm    | 31.98                                                                        | 3.76                                                                         | 2.82                                                   | 1645.7                                   |
| T <sub>5</sub> -Mepiquat chloride @ 2000 ppm    | 35.65                                                                        | 3.95                                                                         | 3.02                                                   | 1724.9                                   |
| T <sub>6</sub> -Chlormequat chloride @ 1000 ppm | 28.44                                                                        | 3.62                                                                         | 2.68                                                   | 1572.5                                   |
| T <sub>7</sub> -Chlormequat chloride @ 1500 ppm | 33.54                                                                        | 3.82                                                                         | 2.87                                                   | 1671.4                                   |
| T <sub>8</sub> -Chlormequat chloride @ 2000 ppm | 26.87                                                                        | 3.49                                                                         | 2.57                                                   | 1521.1                                   |
| T <sub>9</sub> -Ethephon @ 200 ppm              | 24.56                                                                        | 3.31                                                                         | 2.44                                                   | 1459.2                                   |
| T <sub>10</sub> -Ethephon @ 400 ppm             | 25.65                                                                        | 3.38                                                                         | 2.50                                                   | 1482.1                                   |
| T <sub>11</sub> -Ethephon @ 600 ppm             | 27.76                                                                        | 3.56                                                                         | 2.61                                                   | 1540.2                                   |
| Mean                                            | 28.18                                                                        | 3.54                                                                         | 2.62                                                   | 1543.8                                   |
| S. Em (±)                                       | 0.33                                                                         | 0.03                                                                         | 0.03                                                   | 15.1                                     |
| C.D at 5%                                       | 0.96                                                                         | 0.10                                                                         | 0.08                                                   | 44.7                                     |

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