**Effect of Seed Treatments with Selected Plant Growth Regulators and Micronutrients on Growth and Yield attributing Traits of Okra *(Abelmoschus esculentus)* under Drought Condition**

**ABSTRACT**

The present investigation was carried out to evaluate the effect of seed treatments of selected plant growth regulators and micronutrients on growth and yield attributing traits of okra (*Abelmoschus esculentus*) under drought condition. The experiment was laid out in a Randomized Block Design (RBD) with three replications and ten treatments. T0 untreated control was evaluated against, T1 Potassium chloride (KCL), T2 Zinc Sulphate (ZnSO4), T3 Copper Sulphate (CuSO4), T4 Boric Acid (H3BO3), T5 Magnesium Chloride + Zinc Sulphate (MgCl2+ZnSO4), T6 Magnesium Chloride (MgCl2), T7 Gibberellic Acid (GA3), T8 Boric Acid + Copper Sulphate (H3BO3+ CuSO4), T9 Boric Acid + Zinc Sulphate (H3BO3+ ZnSO4) and T9 Trichoderma. The experiment was conducted at Central Research Farm, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, during March to July 2023. The required solution was collected in a beaker, then seeds of okra were soaked in the solution for 8 hours, then the seeds were removed and sown on experimental site. Further growth and yield parameters *viz,* Field emergence, Plant height (30, 60 & 90 DAS), Days to 50% flowering, Number of leaves (30 & 60 DAS), Capsule length and Seed yield per hectare were recorded. Seeds treated with T7 Gibberellic Acid (GA3) recorded higher rate of Field emergence (91.67%), Plant height 30 DAS (20.75cm), Plant height 60 DAS (29.21cm), Plant height 90 DAS (34.78cm), Days to 50% flowering (36.60), Number of leaves 30 DAS (8.07), Number of leaves 60 DAS (25.20), Capsule length (15.25cm), Seed yield per hectare (4.57q), Fruit yield per hectare (74.87q). Based on the results of assessment, it can be concluded that T7 Gibberellic Acid (GA3) soaked for 08 hours showed the best performance in terms of growth and yield attributing traits of okra.

***Keywords:****Okra, Gibberellic acid, Growth, Yield, Parameters, Traits*

1. **INTRODUCTION**

Okra [*Abelmoschus esculents* (L.) Moench] is one of the most important rainy and summer season vegetable crops, belongs to family Malvaceae with 2n=8x=72 or 144 and is polyploid in nature. It is known by many local names in different parts of the world. It is called lady’s finger in England, guino - gombo in Spanish, gumbo in the United States of America, guibeiro in Portuguese and bhindi species in India. It is quite popular in India because of easy cultivation, dependable yield and adaptability to varying moisture conditions **(Chauhan, 1972).**

Okra is an often-cross pollinated crop and predominantly an important vegetable of the tropics and has found its place in India since time immemorial. Almost all parts of Bhendi plant were economical. Seeds are used for oil extraction. Present cultivars of Bhendi are capable of showing high variability in several characters including yield. But the yields of present cultivars per unit area of land and per unit of time are very low because of their very low yield potential **(Balakrishnan and Balakrishnan 1988).**

It is native of tropical and sub-tropical Africa and widely cultivated in India. Uttar Pradesh, Assam, Bihar, Orissa, Maharashtra, West Bengal and Karnataka are important okra producing states. In India, it is grown in an area of 5.07 million hectares with annual production of 58.5 million tons and productivity of 11.5 tons per hectare **(Kumawat *et al*., 2019).**

Okra is cultivated for its green non - fibrous fruits or pods containing round seeds. The fruits are harvested when immature and eaten as a vegetable. Okra fruit can be cooked in a variety of ways. Mature fruits and stems containing crude fiber are used in manufacture of paper, card board and fibres. It is also an excellent source of iodine and is useful for the treatment of goiter. Fruit is useful against genito-urinary disorders, spermatorrhoea and chronic dysentery. It is a good source of vitamins A and B, Protein and minerals. The nutritional value of 100 g of edible okra is characterized 35.0 mg calories, 66.0 mg calcium, 0.35 mg iron, 6.4 g carbohydrates, 103.0 mg potassium, 1.9 g protein, 0.2 g fat, 53.0 mg magnesium, 0.19 mg copper, 1.2 g fiber, 0.01 mg riboflavin, 0.7 g minerals, 0.07 mg thiamine, 56.0 mg phosphorus, 0.06 mg nicotinic acid, 6.9 mg sodium, 13.10 mg Vitamin C, 30.0 mg sulphur and 8.0 mg oxalic acid is present **(Gopalan *et al.,* 2007).**

Germination is considered a critical stage in the life cycle of weed and crop plants **(Radosevich *et al*., 1997).** Genotype, sowing date, time of pod harvest, seed moisture content, and micronutrient applications affect the germination of okra seeds (**Balla *et al*., 2011).** Okra seeds germinate very slowly and unevenly although they are viable seeds. Reduced, delayed, and erratic emergence is a serious problem in okra cultivation caused by seed hardness as it creates problems in rapid germination and uniform field stand **(Purquerio *et al*., 2010).** The hard seed coat restricts the water imbibition and uniform growth and development of the embryo and as a result interferes with seed germination **(Mereddy *et al*., 2015).**

The problem of low germination due to the hard seed coat in okra can be overcome by seed priming. Seed priming is the process of controlled hydration of seeds which is potentially able to promote rapid and more uniform seed germination and plant growth **(Sharma *et al*., 2014).** Priming allows some of the metabolic processes necessary for germination to occur without germination taking place. Seed priming induced synchronized germination, increased seed vigor, and growth of seedlings under stressful conditions *i.e.,* increase in germination and emergence rate **(Bajehbaj, 2010).**

Okra seeds are soaked in water overnight before sowing for softening the hard seed coat and improving seed germination. Seed hardness causes in reduced and delayed seed germination as well as inconsistent emergence in okra cultivation **(Purquerio *et al*., 2010).** The stiff seed coat prevents water absorption and uniform growth of the embryo **(Mereddy *et al*., 2015).** Seed priming is an effective, eco-friendly method to enhance seed germination and seedling vigour **(Nawaz *et al*., 2013; Anuj *et al*., 2021)** and also to overcome the reduced and delayed germination in okra seeds caused by seed hardness **(Anuj *et al*., 2021).** Priming enhances some of the metabolic processes needed for seed germination and under stressful conditions, seed priming results in synchronized germination and enhanced seedling growth **(Bajehbaj, 2010).** When compared to non-primed seeds, primed seeds have higher growth potential and produce a higher yield **(Huang *et al*., 2021).** Different seed priming methods has been used to enhance germination and seed vigor of okra. Among them, Hydro-priming *i.e.* seed soaking in pure water and re-drying to original moisture content before sowing; Osmo-priming *i.e*. soaking the seed in a solution of osmoticum; Hormonal priming i.e. soaking of seeds in different plant growth regulators (GA3, NAA, etc); halo-priming i.e. use of salt solutions for seed soaking, bio-priming i.e. seed imbibition together with biological inoculation (bacteria, fungi, etc.) of seed and solid-matrix priming *i.e.* seed soaking in solid medium (matrix) for controlled water uptake; are commonly used seed priming methods **(Lutts *et al*., 2016).**

The problem of low germination in okra is due to the hard seed coat in okra. The present investigation was conducted to overcome the problem by priming the seeds with different micro-nutrients and growth regulators. Different seed priming treatments were performed to overcome problem of low germination in okra. The investigation also contributed in identifying effective seed priming treatment to enhance the quality of okra crop in water stress condition.

1. **MATERIALS AND METHODS**

The experiment was conducted at Central Research Farm, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, during March to July 2023. Prayagraj is located in the South-East part of Uttar Pradesh, India. The site of experiment is located at 25.57° N latitude, 81.51° E longitude and 98 meter above the sea level. This region has subtropical climate with extreme of summer and winter. The temperature falls to as low as 1°C - 2°C during winter season especially in the months of December and April. The mercury rises to 46°C - 48°C during summer. The average rainfall in this area is around 1013.4 mm annually with maximum concentration during December to April with few showers and drizzles in winter also. The okra variety Superstar was used in the present investigation which is F1 hybrid suitable for Prayagraj conditions. The experiment was laid out in a Randomized Block Design (RBD) with three replications and ten treatments. T0 untreated control was evaluated against, T1 Potassium chloride (KCL), T2 Zinc Sulphate (ZnSO4), T3 Copper Sulphate (CuSO4), T4 Boric Acid (H3BO3), T5 Magnesium Chloride + Zinc Sulphate (MgCl2+ZnSO4), T6 Magnesium Chloride (MgCl2), T7 Gibberellic Acid (GA3), T8 Boric Acid + Copper Sulphate (H3BO3+ CuSO4), T9 Boric Acid + Zinc Sulphate (H3BO3+ ZnSO4) and T9 Trichoderma. To evaluate the effect of seed treatment on okra various growth and yield attributing parameters *viz,* Field emergence, Plant height (30, 60 & 90 DAS), Days to 50% flowering, Number of leaves (30 & 60 DAS), Capsule length, Seed yield per hectare and Fruit yield per hectare were recorded and statistically analyzed.

**2.1 Preparation of Solutions**

**2.1.1 Preparation of Control Solution**

To accomplish this treatment, tap water was collected in a beaker, seeds of okra were soaked in the solution for 8 hours, seeds were removed and shade dried, seeds were sown on experimental site.

**2.1.2 Preparation of Micro-nutrient Solution**

To accomplish this treatment, micronutrients such as Potassium chloride (KCl), Zinc Sulphate (ZnSO4), Copper Sulphate (CuSO4), Boric Acid (H3BO3), Magnesium Chloride + Zinc Sulphate (MgCl2 + ZnSO4), Magnesium Chloride (MgCl2) respectively were used. The micronutrient compounds were put in separate beakers. 0.5% solution was prepared by adding 1g of micronutrient compound in 200ml distilled water. The seeds of okra were soaked in the solution for 8 hours, seeds were removed and shade dried, seeds were sown on experimental site.

**2.1.3 Preparation of Growth Hormone Solution**

To accomplish this treatment, growth hormone such as Gibberellic Acid (GA3) was used. The growth hormone compounds were put in separate beakers. 0.5% solution was prepared by adding 1g of growth hormone compound in 200ml distilled water. The seeds of okra were soaked in the solution for 8 hours, seeds were removed and shade dried, seeds were sown on experimental site.

1. **RESULTS AND DISCUSSION**

The data recorded on growth and yield attributing traits of okra *viz,* Field emergence, Plant height (30, 60 & 90 DAS), Days to 50% flowering, Number of leaves (30 & 60 DAS), Capsule length, Seed yield per hectare and Fruit yield per hectare have been presented below in table 1. Analysis of variance revealed that the difference among eleven treatments were significant for seedling parameters and growth and yield parameters given below.

**3.1 Field Emergence (%)**

The data recorded on field emergence are presented in table 1. The mean performance of field emergence ranged from 62.50% to 91.67% with mean value of 77.27%. The highest percent of field emergence 91.67% was reported in T7 (Gibberellic Acid), followed by 87.5% in T10 (Trichoderma) and 83.33% in T4 (Boric Acid), while lowest percent of field emergence 62.5% was reported in T0 (Control). Similar findings were reported by **Ullah Arshad (2002).**

* 1. **Plant Height (cm) at 30 DAS**

The data recorded on plant height at 30 DASare presented in table 1 and figure 1. The mean performance of plant height at 30 DASranged from 12.77cm to 20.75cm with mean value of 17.75cm. The highest plant height at 30 DAS20.75cm was reported in T7 (Gibberellic Acid), followed by 19.73cm in T9 (Boric Acid + Zinc Sulphate) and 19.23cm in T10 (Trichoderma), while lowest plant height at 30 DAS 12.77cm was recorded in T0 (Control). Similar findings were reported by **Bello (2015).**

Similar findings reported by **Sakamoto *et al.,* (2004)** demonstrated that overexpression of a gene involved in gibberellin biosynthesis led to increased stem elongation and plant height in rice. **Fleet and Sun (2005)** showed that exogenous application of gibberellic acid resulted in taller plants with longer internodes in *Arabidopsis thaliana*.

In conclusion, gibberellic acid promotes plant height by stimulating cell division and elongation, interacting with auxin signaling pathways, and modulating gibberellin biosynthesis and signaling. These findings underscore the importance of gibberellic acid in regulating plant growth and development, with potential applications in agriculture for increasing crop yields and improving plant architecture.

**3.3 Plant Height (cm) at 60 DAS**

The data recorded on plant height at 60 DASare presented in table 1 and figure 1. The mean performance of plant height at 60 DASranged from 23.14cm to 29.21cm with mean value of 26.85cm. The highest plant height at 60 DAS29.21cm was reported in T7 (Gibberellic Acid), followed by 28.27cm in T9 (Boric Acid + Zinc Sulphate) and 27.77cm in T4 (Boric Acid), while lowest plant height at 60 DAS23.14cm in was reported in T0 (Control). Similar findings were reported by **Bello (2015).**

**3.4 Plant Height (cm) at 90 DAS**

The data recorded on plant height at 90 DASare presented in table 1 and figure 1. The mean performance of plant height at 90 DASranged from 27.86cm to 34.78cm with mean value of 31.55cm. The highest plant height at 90 DAS34.78cm was reported in T7 (Gibberellic Acid), followed by 32.71cm in T9 (Boric Acid + Zinc Sulphate) and 32.053cm in T4 (Boric Acid), while lowest plant height at 90 DAS 27.86cm was reported in T0 (Control). Similar findings were reported by **Bello (2015).**

**3.5 Days to 50 % Flowering**

The data recorded on days to 50% flowering are presented in table 1 and figure 1. The mean performance of days to 50% flowering ranged from 36.60 to 41.20 with mean value of 38.91. The highest days to 50% flowering 36.60 was reported in T7 (Gibberellic Acid), followed by 37.47 in T9 (Boric Acid + Zinc Sulphate) and 38.27 in T5 (Magnesium Chloride + Zinc Sulphate), while lowest days to 50% flowering 41.20 was reported in T0 (Control). Similar findings were reported by **Dhage (2011).**

Similar findings reported by **Achard *et al.,* (2007)** demonstrated that exogenous application of gibberellic acid accelerated flowering in *Arabidopsis thaliana* by promoting the expression of floral meristem identity genes. **Cheng *et al.* (2004)** showed that GA-deficient mutants in rice exhibited delayed flowering compared to wild-type plants.

**3.6 Number of Leaves at 30 DAS**

The data of number of leaves at 30 DASis presented in in table 1 and figure 1. The mean performance of number of leaves at 30 DASranged from 4.67 to 8.07 with mean value of 6.45. The highest number of leaves at 30 DAS8.07 was reported in T7 (Gibberellic Acid), followed by 7.33 in T9 (Boric Acid + Zinc Sulphate) and 6.60 in T4 (Boric Acid), while lowest leaves at 30 DAS 4.67 was reported in T0 (Control). Similar findings were reported by **Bello (2015).**

**3.7 Number of Leaves at 60 DAS**

The data recorded on number of leaves at 60 DASis presented in table 1 and figure 1. The mean performance of number of leaves at 60 DASranged from 18.40 to 25.20 with mean value of 21.54. The highest number of leaves at 60 DAS25.20 was reported in T7 (Gibberellic Acid), followed by 23.20 in T9 (Boric Acid + Zinc Sulphate) and 22.33 in T3 (Copper Sulphate), while lowest number of leaves at 60 DAS 18.40 was reported in T0 (Control). Similar findings were reported by **Bello (2015).**

Similar findings reported by **Kondo *et al.,* (2018)** investigated the effect of exogenous gibberellic acid application on growth and flowering in buckwheat. The study found that GA treatment significantly increased plant height and promoted earlier flowering, but did not specifically report effects on leaf number. **Ma *et al.,* (2018)** explored the role of gibberellin biosynthesis genes in buckwheat growth and development. Although this study did not directly assess the effect of GA application on leaf number, it provided insights into the genetic regulation of growth processes in buckwheat, which may indirectly relate to leaf development.

**3.8 Capsule Length (cm)**

The data reported on capsule length is presented in table 1 and figure 1. The mean performance capsule length ranged from 9.85cm to 15.25cm with mean value of 12.57cm. The highest capsule length 15.25cm was reported in T7 (Gibberellic Acid), followed by 13.45 in T9 (Boric Acid + Zinc Sulphate) and 13.34 in T5 (Magnesium Chloride + Zinc Sulphate), while lowest capsule length 9.85 was reported in T0 (Control).

**3.9 Seed Yield per hectare**

The data recorded on seed yield per hectare is presented in table 1 and figure 1. The mean performance of seed yield per hectare ranged from 2.51q/ha to 4.57 q/ha with mean value of 3.16q/ha. The highest seed yield per hectare 4.57q/ha was reported in T7 (Gibberellic Acid), followed by 3.98q/ha in T9 (Boric Acid + Zinc Sulphate) and 3.19 q/ha in T4 (Boric Acid), while lowest seed yield per hectare 2.51q/ha was reported in T0 (Control). Similar findings were reported by **Bello (2015).**

Similar findings reported by, **(Morrison *et al.,* 2000)** in soyabeanand **(Durgbanshi *et al.,* 2005)** in tomato, have demonstrated that GA application can lead to increased flower and fruit production, ultimately contributing to higher seed yield. **(Yamamoto *et al.,* 2001)** in rice and **(Chono *et al.,* 2003)** in barley, has shown that GA treatment can increase seed size and weight, resulting in higher seed yield per plant.

**3.10 Fruit Yield per hectare**

The data recorded on fruit yield per hectare is presented in table 1 and figure 1. The mean performance of fruit yield per hectare ranged from 41.87q/ha to 74.87q/ha with mean value of 58.34q/ha. The highest fruit yield per hectare 74.87q/ha was reported in T7 (Gibberellic Acid), followed by 64.70q/ha in T9 (Boric Acid + Zinc Sulphate) and61.63q/ha in T10 (Trichoderma), while lowest fruit yield per hectare 41.87q/ha was reported in T0 (Control). Similar findings were reported by **Bello (2015).**

Similar findings reported by, **(Srinivas *et al.,* 2019)** intomato and **(Kumar *et al.,* 2018)** in citrus, have demonstrated that GA treatment can improve fruit set and yield by promoting flowering and pollination. **(Kumar *et al.,* 2013)** in grape and **(Khan *et al.,* 2016)** inapple, has shown that GA application can increase fruit size and weight, resulting in higher fruit yield per plant.

**Table 1: Effect of seed treatments of selected plant growth regulators and micronutrients on growth and yield attributing traits of okra**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Field Emergence****(%)** | **Plant Height (cm)** | **Days to** **50 % Flowering** | **Number of Leaves** | **Capsule Length (cm)** | **Seed yield per****hectare****(q/ha)** | **Fruit yield per hectare****(q/ha)** |
| **30 DAS** | **60 DAS** | **90 DAS** | **30 DAS** | **60 DAS** |
| **T0** | 62.500 | 12.767f | 23.140e | 27.860e | 41.200a | 4.667d | 18.400d | 9.853f | 2.513f | 41.867g |
| **T1** | 70.833 | 16.967e | 26.553cd | 30.173d | 39.133c | 6.400bc | 21.200c | 11.733e | 2.957de | 55.867de |
| **T2** | 75.000 | 18.320cd | 27.127bc | 31.800bc | 38.600cd | 6.067c | 21.733bc | 13.153**b** | 2.893de | 50.167f |
| **T3** | 79.167 | 18.833bc | 27.193bc | 31.720bc | 40.400b | 6.267c | 22.333bc | 12.433cd | 2.577f | 58.533cd |
| **T4** | 83.333 | 18.553bcd | 27.767abc | 32.053bc | 39.067c | 6.600bc | 22.067bc | 12.487c | 3.193c | 53.800e |
| **T5** | 75.000 | 16.833e | 26.887bc | 31.593bcd | 38.267d | 6.133c | 21.000c | 13.340b | 2.817e | 60.267c |
| **T6** | 70.833 | 16.233e | 27.007bc | 31.100cd | 39.067c | 6.667bc | 20.667c | 11.833de | 3.253c | 60.433c |
| **T7** | 91.667 | 20.753a | 29.207a | 34.780a | 36.600f | 8.067a | 25.200a | 15.253a | 4.570a | 74.867a |
| **T8** | 75.000 | 17.487de | 25.180d | 31.273bcd | 39.067c | 6.467bc | 20.600c | 11.493e | 2.960de | 59.633c |
| **T9** | 79.167 | 19.727ab | 28.273ab | 32.713b | 37.467e | 7.333ab | 23.200b | 13.447b | 3.983b | 64.700b |
| **T10** | 87.500 | 19.227bc | 27.033e | 31.953bc | 39.200c | 6.333bc | 20.600c | 13.267b | 3.077cd | 61.633bc |
| **Grand Mean** | **77.272** | **17.790** | **26.851** | **31.547** | **38.91527** | **6.454636** | **21.54545** | **12.572** | **3.163** | **58.34245** |
| **S.Em** | **4.35** | **0.25** | 0.31 | **0.30** | **0.15** | **0.20** | **0.37** | **0.13** | **0.05** | **0.66** |
| **S.Ed** | **6.15** | **0.35** | **0.44** | **0.42** | **0.22** | **0.28** | **0.53** | **0.18** | **0.06** | **0.93** |
| **CD at 5%** | **-** | **1.280** | **1.59** | **1.509** | **0.785** | **1.007** | **1.900** | **0.643** | **0.232** | **3.354** |

1. **CONCLUSION**

From the results of the assessment, it is observed that the different seed treatments of selected plant growth regulators and micronutrients show significant results on growth and yield attributing traits of okra expect for field emergence. The seeds treated with T7 (Gibberellic Acid) reported higher rate of Field emergence (91.67%), Plant height at 30 DAS (20.75cm), Plant height at 60 DAS (29.21cm), Plant height at 90 DAS (34.78cm), Days to 50% flowering (36.60), Number of leaves at 30 DAS (8.07), Number of leaves at 60 DAS (25.20), Capsule length (15.25cm), Seed yield per hectare (4.57q/ha), Fruit yield per hectare (74.87q/ha). Overall, it can be concluded that seeds treated with Gibberellic Acid (GA3) for 08 hours have performed best in terms of growth and yield attributing traits of okra.

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