**Original Research Article**

**Studies on effect of seed treatment with micronutrients and plant growth regulator on vegetative and reproductive growth in cucumber (*Cucumis sativus* L.)**

**ABSTRACT**

|  |
| --- |
| **Background:** To assess the effect of micronutrient and plant growth regulators in cucumber crop, the experiment was carried out in randomized complete block design (RCBD) having three replications at Department of Horticulture (Vegetable & Floriculture), Bihar Agricultural College, Sabour, Bhagalpur during summer season of 2021.  **Methods:** The seed material comprised of single seed lot of cucumber *var.* Pusa Barkha, which was treated with ZnSO4 (50, 75ppm) and FeSO4 (100, 125 ppm) and foliar spray of Ethrel (100, 200, 300 ppm), at 2-4 true leaf stage. Vegetative,reproductive parameters were recorded.  **Results:** The seed treatment with Zn(75 ppm) for 12 hour followed by foliar spray of Ethrel(200ppm) at 2-4 leaf stage resulted in highest improvement in almost all parameters except days to 50% flowering which was lowest for seed treatment with Zn(50ppm).The treatment with Zn (75ppm) for 12 hour along with foliar spray of Ethrel (200ppm) at 2-4 leaf stage was found the most promising and effective for improving the crop performance.  **Conclusion: I**t was concluded that each and every seed treatment with micronutrient followed by foliar application of plant growth regulator given variable response of treatments. |

**Keywords:** Cucumber,Seed treatment, micronutrients, Ethrel

1. **INTRODUCTION**

“The good harvest in almost all crops depends on several factors; one among them is quality seed and also performance of other inputs depend on this factor. Good seed in good soil realize good yield. The role of seed in agriculture is very much significant, particularly in developing countries like India where the population and GDP considerably depend upon agriculture (Tyagi, 2012)”. A good vigorous seed utilizes all the resources and realized a reasonable output to the grower.

“Cucumber (*Cucumis sativus* L.) had been cultivated over 3000 years in India. Cucumber is also known as’ Khira’ in India which is extensively grown in tropics, subtropics and milder temperate zones. It is most widely cultivated cucurbits after watermelon and seed oil is also used as antipyretic. Nutrient content- protein (0.4%), carbohydrate (1.5mg), iron (2mg) and also contain Vitamin C. The immature fruit of cucumber is used as salad and for pickling. The fruits are also used as raw. The total area under cultivation of cucumber covers in India is 105.0 lakh hectare with annual production of 163.0 lakh million tonne” (National Horticulture Board, 2019-20).

“ Micronutrients are involved in key physiological processes in crop plant *viz*., photosynthesis, respiration” (Marschner,1995) and their deficiency can inhibit this vital physiological process thus limiting yield gain. “Application of micronutrients at early stage of reproduction phase in plant makes significant improvement in pollen fertility, pollen stigma interaction and seed setting” (Pandey, 2010). “Seventeen micronutrients play crucial role in growth and development of any crop vis a vis cucumber plant. Seed treatment is one of the key techniques for improvement of crop performance in several crops. Seed treatment with micronutrients potentially provides a simple and inexpensive method for improving micronutrient in plant nutrition” (Farooq *et al.,* 2012). “It also helps in membrane stabilization, free radical detoxification and several other activities in plant. Radical detoxicification improves the antioxidants and maintain the cellular homeostasis” (Manne et al., 2024; Manne et al., 2025; Kumari et al., 2024; Sonia et al., 2023; Nain et al., 2025). “Use of plant growth regulators such as ethephon shows promising results in enhancing the yield of cucumbers” (Santos and Guanzon, 2024).”There is a scanty of study available to assess the effect of micronutrient either individual or in combination with plant growth regulator (PGR) for improvement in vegetative as well as reproductive growth in vegetable crops especially, cucumber. The most applicable and widely used should be organic fertilizers in the agricultural industry, as the seed germination rates and root and shoot elon gations were observed high in tomato and cucumber” (Pan *et al.,* 2022). Exploring how seed treatment with micronutrients and plant growth regulators (PGRs) affects cucumber growth is really important for boosting germination, seedling vigor, and getting plants off to a strong start. It helps ensure that plants take in the right nutrients, which leads to better root and shoot development, ultimately improving their overall health and also using PGRs can help balance hormones in the plants, which promotes better flowering, fruit set, and higher yields. On top of that, treating seeds can cut down on the need for excessive fertilizer, making farming more sustainable and cost-effective. “Keeping in view the above fact regarding role of micronutrients and PGR on vegetative and reproductive growth in cucumber, the present investigation has formulated with the objective to assess the impact of ZnSO₄, and FeSO₄ seed treatment along with Ethrel foliar spray on yield and growth of cucumber. This research is key to pushing forward precision agriculture and creating effective strategies for growing cucumber crops”.

1. **METHODOLOGY:**

The investigation was carried out a vegetable seed production area of Department of Horticulture (Vegetable & Floriculture), Bihar Agricultural College, Sabour, Bhagalpur during summer season of 2021. Geographically, Sabour is situated under humid subtropical climate and located in between 82.120 and 83.980 E longitude and 24.470 and 26.560 N latitude at an altitude of 75m above the mean sea level in the Indo -Gangetic Plains of North Eastern India. The soil of the experimental plot was sandy loam. The experiment was carried out in randomized complete block design (RCBD) having three replications and 20 treatments. Seeds were sown in pits with spacing of 2.5m between the rows and 0.40m between the plants and recommended dose of FYM and NPK were incorporate the soil. Each treatment was accommodated in plot size of 2.50 X 2.0 m. The crop was irrigated once in seven to ten days interval after proper establishment of the plants.The experiment was conducted taking two factors i.e., seed treatment of different concentration of micronutrient (Fe and Zn) and different concentration plant growth regulator (Ethrel) for foliar spray at 2-4 leaf stage in cucumber. The single seed lot of cucumber *var*. Pusa Barkha was treated with micronutrient solution *viz*., FeSO4 (100, 125 ppm) and ZnSO4 (50, 75 ppm) and foliar spray of Ethrel (100, 200, 300 ppm) and their different combinations to assess their effect on vegetative and reproductive growth. The seed was soaked in FeSO4 (100, 125 ppm) and ZnSO4 (50, 75 ppm) solution for 12 hour and afterwards, the same was dried at room temperature to maintain the initial seed moisture content. Further, foliar spray with Ethrel (100, 200, 300 ppm) was done at 2-4 true leaf stage.

The following observations were recorded:

Treatment and replication wise five plants were selected randomly and Vegetative,reproductive parameters were recorded.

* 1. **Number of branches**

Number of branches was calculated by counting the branches arising from the vine at 60DAS from randomly selected plants and mean was calculated.

* 1. **Internodal length(cm)**

The internodal length was recorded by measuring the length between two nodes at 60 DAS from randomly five selected plants and mean was worked out and expressed in centimeter.

* 1. **Plant length**

The plant length was recorded by determining the measurement location from where the plant contacts the soil to the top of the plant with the help of meter scale at 60DAS and mean was taken and expressed in centimeter.

* 1. **Days to 50 per cent flowering**

Number of days required for the appearance of first female flower was recorded on five plants under each treatment and average days for appearance of first female flower per plant was worked out**.**

* 1. **Number of fruit/ plants**

The matured fruits were harvested and counted in each picking and total number of fruits were recorded by adding number of fruits in each treatment and the average was calculated.

* 1. **Fruit length(cm)**

The length of the fruit was determined with the help of measuring tape and mean value was recorded and expressed in centimeter.

* 1. **Fruit diameter (cm)**

Diameter of matured fruits was calculated by measuring five randomly selected fruits from all treatment combination in each replication. The fruit diameter measurement was taken from the middle portion of the fruit with the help of Vernier Caliperse scale and average was calculated and expressed in centimeter.

* 1. **Fruit weight (g)**

Immediately after harvest, the fruits were weighed on electronic weighing balance and the average fruit weight of five fruit was worked out and expressed in gram.

* 1. **Statistical analysis:**

The mean value of observations recorded on different parameters were subjected to statistical analysis. ANOVA, standard error of differences (SEd), Standard error of means (SEm), Critical difference (CD) and coefficient of variation (CV) were calculated.



FIG.1: Cucumber crop from the field

1. **RESULTS AND DISCUSSION:**

The mean values of different parameters ranged as number of branches per pant (2.56-4.84), internodal length (6.50-7.36 cm), vine length (152.78-219.78cm), days to 50 percent flowering (38.33-45.33), number of fruits per vine (3.89- 7.33), fruit length (20.95-30.74 cm), fruit diameter (0.32-1.54 cm), fruit weight (469.33-574.50 gram) in the cucumber seed lot after treatment of seed with micronutrient (Fe and Zn) followed by foliar spray of plant growth regulator (Ethrel) (table1).

**Number of branches per plant**

All the treatment enhanced the number of branches (0.20- 2.28) over untreated seed lot (2.56). The Treatment with Zn (75 ppm), Ethrel (100, 200, 300 ppm) resulted in improvement in number of branches by 0.66 to 1.37. Among combination of micronutrient and plant growth regulator at different concentration, the highest number of branches was recorded in case of seed treatment with Zn (75ppm) and foliar spray of Ethrel (200ppm) at 2-4 true leaf stage i.e., 2.28 over untreated seed lot which was also highest among all the treatments. The lowest improvement (0.2) in number of branches was observed in case of Fe (125 ppm).Rafeekher *et al*., 2001 observed that the foliar application of Ethrel (200 ppm) at 2 and 4 true leaf stage increased number of branches per plant in cucumber. Also, the Ethrel (250 ppm) sprayed at 2 and 4 true leaf stages increased the number of branches per plant in sponge gourd *var*. Pusa chikani (Girde *et al*., 2006).The foliar application of other plant growth regulators like Ethrel (100, 200ppm), MH(100, 200ppm), NAA(50, 100ppm) in cucumber at 2-4 true leaf stage increased higher number of branches per vine (Thappa *et al*., 2011).

**Internodal length:**

All the treatment combination has enhanced the internodal length over untreated (6.50) but, it was comparable with untreated seed lot. The highest improvement was observed in seed treatment with Zn (50 ppm) followed by Ethrel (200 ppm).

**Vine length (VL,cm):**

The effect on vine length was at par with the untreated seed lot. Among combination of micronutrient and plant growth regulator at different concentration, the highest vine length was recorded in case of Zn (50 ppm) and foliar spray of Ethrel (200ppm) at 2-4 true leaf stage which was 0.86 cm over untreated seed lot. This improvement in vine length was also found highest among all treatment and its combination. The lowest vine length was observed in untreated seed lot i.e., 0.08 cm.Rai *et al.,*2003 found that the foliar application of 100 mg/l paclobutrazol at two (2) true leaf stage as soil drenching around the plant were recorded maximum improvement in vine length in bitter gourd *cv.* Meghalaya local.The foliar application of other growth hormone like GA3 (50ppm), which was applied at three times at 2 and 4- leaf stage in bitter gourd resulted in highest number of vine length(396.11cm).Further, Ethrel (300ppm) sprayed at 2-4 true leaf stage in cucumber resulted in higher vine length (131.88cm) and number of branches per plant (9.87) (Ajay *et al*., 2018).

**Days to 50% Flowering (DF, days):**

The seed treatment with Zn (50 ppm) alone significantly reduced DF by 14.79 %. However, effect of Ethrel (100, 200, 300 ppm) alone was at par with untreated. Among combination of treatment, the lowest DF was recorded in case of Fe (100ppm) and Ethrel (300ppm) which was 6.82 per cent lower. The highest DF was observed with Fe (100ppm) and Ethrel (200ppm) i.e., 45.33 days.

**Number of fruits per vine:**

All the treatment enhanced the number of fruits per vine (1.37-2.45) over untreated (3.89). The Zn (75 ppm) and Ethrel (300 ppm) alone significantly enhanced the number of fruits per vine by 1.67 and 2.0, respectively. Among combination, the highest number of fruits was recorded in case of Zn (75ppm) and foliar spray of Ethrel (200ppm) at 2-4 true leaf stage which was 3.44 over control; this improvement was also found highest among all treatment and its combination. The lowest number of fruits per vine was observed in control i.e., 3.89.The application of NAA 100 ppm through foliar spray at 2 and 4 leaf stages increased the number of fruits per plant in *cv.* Patiwalli of bottle gourd (Patel *et al*.,1992). The application of Ethrel (150 ppm) sprayed at 4 leaf stage increased number of fruits per plant in pumpkin (Das and Maurya, 1993).The application of GA3(50 ppm) was applied at 2 and 4 leaf stage in bitter gourd exhibited significantly increased number of fruits per vine (8.85) (Hirpara *et al.,* 2014).

Chaurasiya *et al*., (2016) found that the Ethrel(100ppm) which was applied at 2 and 4-leaf stage in muskmelon resulted in increasing the number of days to first female flower (43.58), enhanced number of pistillate flower per plant 17.05), least sex ratio (7.19), maximum number of fruits per plant (4.52) and yield per hectare (350.90).

**Fruit length (cm):**

Almost all the treatment enhanced the fruit length (5.05- 9.79cm) over control (20.95cm). The Fe (100, 125 ppm), Zn (50, 75 ppm) and Ethrel (100, 200, 300 ppm) enhanced the fruit length which was at par with control. Among combination, the highest fruit length was recorded for Zn (75ppm) and foliar spray of Ethrel (200ppm) which was 9.79 cm over control; this improvement was also found highest among all selected treatment. The lowest enhancement (5.05 cm) was observed for Fe (125 ppm) followed by Ethrel (300 ppm).The foliar application of 100ppm Ethrel at 2 and 4-leaf stage along with seed soaking by boron (0.05%) for 12 hours in bitter gourd, resulted in increased number of fruits per vine, fruit length and ultimately yield per hectare (Ansari *et al*., 2018).

**Fruit diameter (cm):**

Each and every treatment in present study improved the fruit diameter (0.32-1.54 cm) over untreated (5.63 cm). The treatment with Fe (100, 125 ppm), Zn (50, 75 ppm) and Ethrel (100, 200, 300 ppm) enhanced the fruit diameter which was at par with untreated seed lot. Among combination, the highest fruit diameter was recorded with Zn (75ppm) and foliar spray of Ethrel (200ppm) which was 1.54 cm over control; this improvement was also found highest among all treatment under study. The lowest improvement (0.86 cm) in fruit diameter was observed in case of Zn (50 ppm) followed by Ethrel (200 ppm).

**Fruit weight (gram):**

Seed treatment with Fe (100 ppm) and Zn (75 ppm) enhanced the fruit weight which was at par with untreated seed lot. Further, Ethrel (100 ppm) resulted in highest improvement in fruit weight which was 115.67 gram higher in comparison with control. Among combination, the highest fruit weight was recorded in case of Zn (75ppm) and Ethrel (200ppm) which was 105.17 gram over control. The lowest improvement (81.78 gram) in fruit diameter was observed in case of Zn (50 ppm) followed by Ethrel (200 ppm).

These finding was also reported by several other researchers in cucurbitaceous crop. The Ethrel (150 ppm) was applied at 2 and 4 leaf stage through foliar spray in muskmelon exhibited the one best treatment in decreasing the number of days to first female flower (43.58), enhanced number of pistillate flower per plant 17.05), least sex ratio (7.19), maximum number of fruits per plant (4.52) and yield per hectare (350.90) (Chaurasiya *et al.,*2016). The application of Ethephon and Maleic hydrazide were applied at 2-leaf and 4- leaf stage in cucumber and observed that foliar application of 200ppm Ethephon decreased the vine length but increased primary number of branches, fruit yield per vine (Kaur *et al.,*2016).

The Ethrel (600 ppm) was applied in bottle gourd influenced the morphological attributes such as vine length, number of nodes and internodal length and also observed maximum number of female flowers, minimum number of male flower and ultimately maximum number of fruit (Patel *et al.,*2017). Application of ethereal increases number of female flowers and suppresses the male blooms by altering the sex ratio which increased the yield parameters (Sharma *et al.,*2024). The application of 300ppm Ethrel was applied at 2-leaf and 4- leaf stage in cucumber under polyhouse condition resulted in higher vine length (131.88cm), number of branches per plant (9.87), and internodal length (Ajay *et al*., 2018).The foliar application of micronutrient like iron (0.2%), boron (0.1%), applied in chilli at 60, 90 and 120 days after transplanting, significantly increased plant height (70.02cm), number of primary branches per plant (8.51), plant spread (36.13 cm), number of fruits per plant (47.80), dry fruit yield per ha (52.61 q ha-1), average fruit weight (6.64 g), fruit length (10.52 cm) and fruit width (1.36 cm) (Malik *et al*., 2020).

From present study, it was concluded that each and every seed treatment with micronutrient followed by foliar application of plant growth regulator given variable response of treatments, yet the treatment with Zn (75ppm) for 12 hours along with foliar spray of Ethrel (200ppm) at 2-4 leaf stage was found the most promising and effective for improving the crop performance i.e vegetative and reproductive growth in cucumber crop.

**Table 1:** Mean value of different vegetative and reproductive growth parameters

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Number**  **of branches** | **Internodal length (cm)** | **Vine**  **length (cm)** | **Days to 50**  **%**  **flowering** | **Number**  **of fruits per vine** | **Fruit**  **Length (cm)** | **Fruit**  **diameter (cm)** | **Fruit**  **weight (g)** |
| Untreated | 2.56 | 6.50 | 152.78 | 44.00 | 3.89 | 20.95 | 5.63 | 469.33 |
| Fe (100ppm) | 2.93 | 6.58 | 162.66 | 40.00 | 5.27 | 20.42 | 5.55 | 493.60 |
| Fe (125ppm) | 2.76 | 6.12 | 162.11 | 40.33 | 5.26 | 21.41 | 5.95 | 568.67 |
| Zn (50ppm) | 3.00 | 5.99 | 170.22 | 38.33 | 5.35 | 20.50 | 5.79 | 555.23 |
| Zn (75ppm) | 3.22 | 6.46 | 172.00 | 39.00 | 5.56 | 21.83 | 5.84 | 499.90 |
| Ethrel (100ppm) | 3.33 | 6.32 | 170.44 | 43.67 | 5.67 | 22.32 | 6.00 | 585.00 |
| Ethrel (200ppm) | 3.81 | 6.56 | 177.67 | 43.33 | 5.71 | 23.20 | 6.19 | 553.33 |
| Ethrel (300ppm) | 3.93 | 6.49 | 181.56 | 43.33 | 5.89 | 22.83 | 6.11 | 395.33 |
| Fe (100ppm) + Ethrel (100ppm) | 3.75 | 6.39 | 178.00 | 44.00 | 5.78 | 23.16 | 5.91 | 570.00 |
| Fe(100ppm)+ Ethrel (200ppm) | 4.05 | 6.60 | 187.34 | 45.33 | 5.88 | 24.08 | 6.22 | 446.50 |
| Fe(100ppm) + Ethrel (300ppm) | 4.09 | 7.18 | 194.67 | 41.00 | 6.00 | 21.38 | 6.42 | 457.27 |
| Fe(125ppm) + Ethrel (100ppm) | 3.67 | 6.31 | 175.33 | 43.66 | 5.70 | 22.80 | 5.98 | 567.83 |
| Fe (125ppm) + Ethrel (200ppm) | 3.78 | 6.69 | 181.11 | 44.33 | 5.69 | 21.83 | 6.06 | 439.17 |
| Fe (125ppm)+ Ethrel (300ppm) | 3.89 | 6.59 | 181.78 | 42.33 | 5.79 | 26.00 | 6.39 | 459.00 |
| Zn (50ppm) + Ethrel (100ppm) | 4.00 | 7.19 | 190.89 | 43.66 | 5.98 | 23.66 | 6.33 | 457.56 |
| Zn (50ppm) + Ethrel (200ppm) | 4.22 | 7.36 | 200.66 | 43.00 | 5.99 | 23.73 | 6.49 | 551.11 |
| Zn (50ppm) + Ethrel (300ppm) | 4.41 | 7.33 | 207.44 | 42.00 | 6.11 | 24.00 | 6.55 | 520.23 |
| Zn (75ppm) +Ethrel (100ppm) | 4.44 | 7.07 | 211.67 | 42.33 | 6.33 | 28.03 | 6.68 | 530.00 |
| Zn (75ppm) +Ethrel (200ppm) | 4.84 | 6.89 | 219.78 | 43.00 | 7.33 | 30.74 | 7.17 | 574.50 |
| Zn (75ppm) + Ethrel (300ppm) | 4.33 | 6.97 | 207.45 | 44.33 | 6.24 | 28.33 | 6.93 | 511.67 |
| CD (p<0.01) | 0.476 | NS | 19.64 | 3.760 | 0.684 | 3.478 | 0.807 | 71.47 |

**CONCLUSION:**

The seed material comprised of single seed lot of cucumber var. Pusa Barkha which was treated with micronutrients (ZnSO4, FeSO4) at two level of concentration (100, 125ppm and 50, 75ppm) along with foliar application of Ethrel at three concentrations (100, 200, 300ppm) applied at field level and evaluate each and every treatment in cucumber crop. The seed treatment with micronutrients and/or foliar application of plant growth regulator, the improvement was observed in number of branches, internodal length(cm),vine length(cm), days to 50 per cent flowering, number of fruits per vine, fruit length(cm), fruit diameter(cm), fruit weight(g).The seed treatment with Zn(75 ppm) for 12 hour followed by foliar spray of Ethrel(200ppm) at 2-4 leaf stage resulted in highest improvement in almost all parameters except days to 50% flowering which was lowest for seed treatment with Zn(50ppm).From present study, it was concluded that each and every seed treatment with micronutrient followed by foliar application of plant growth regulator given variable response of treatments, yet the treatment with Zn (75ppm) for 12 hour along with foliar spray of Ethrel (200ppm) at 2-4 leaf stage was found the most promising and effective for improving the crop performance. Incorporating these micronutrients at the early stage enhances early nutrient uptake which reduce fertilizer usage that leads to Cost-effective & sustainable farming and also Enhances stress resistance which helps plants tolerate drought, salinity, or diseases.

**Disclaimer (Artificial intelligence)**

**Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.**

**References**

1. Ajay SK, Asati KP, Barche S and Tulasigeri RG. Effect of Different Plant Growth Regulators on Growth, Yield and Quality Parameters in cucumber (*Cucumis sativus* L.) under Polyhouse Condition. International Journal of Current Microbiology and Applied Science 2018, (7):04- 2319-7706.
2. Anonnumous. Area and production of cucumber in India. National horticulture board, India 2019.
3. Ansari AM and Chowdhary BM. Effect of boron and plant regulators on vegetative, physiological and fruit characters of bottle gourd (*Lagenaria siceraria* (Mol.) Standl] Progressive Research 2018;9:974-978.
4. Chaurasiya J, Verma RB, Mukhtar A, Adarsh A, Kumar R and Pratap T. Influence of plant growth regulators on growth sex expression yield and yield quality of Muskmelon (*Cucumis melo* L.). Ecology Environment and Conservation 2016;(S39-S43):0971-765X.
5. Das TK and Maurya AN. Efficacy of growth regulating substances on different attributes of yield of Cucurbita moschata Poir. Orissa J. on Agril. Res 1993;5(1, 2):69- 74.
6. Farooq M, Wahid A, Kadambot and Sidique HM. Micronutrient application through seed treatment-a review, Journal of soil science and plant nutrition 2012;12(1):125-142.
7. Girde VB, Bhortake S, Ingle VG, Pandey VP and Ghode PB. Effect of plant growth regulators on growth, sex expression and yield of sponge gourd cv. Pusa chikani. Crop. Prod. 2006;2(1):92-93.
8. Hirpara JA, Vaddoria MA, Jivani LL and Patel JB, AM. Seed yield and quality as influence by plant growth regulators and stages of spray in bitter gourd. An international e-journal 2014;3(3):282-287.
9. Kaur A, Khurana DS and Dhall RK. Sex Modification in cucumber (*Cucumis sativus* L.) under the influence of Ethephone and Maleic Hydrazide. Int. J. Adv. Res 2016;4(11):2199-2205.
10. Kumari N, Rani B, Manne H, Jattan M, Sushil, Avtar R, Kumari A, Duhan J, and Kodidhala V. Antioxidative responses mechanisms in halophytes: their role in stress defense. In: Dagar, J.C., Gupta, S.R., Kumar, A. (eds). Halophytes vis-à-vis saline agriculture: perspectives and opportunities for food security. Springer, Singapore. 2024, 329-350
11. Malik AA, Narayan S, Magray MM, Shameem S, Hussain and Bangroo S. Effect of foliar application of micronutrients on growth, yield, quality and seed yield of chilli (*Capsicum annuum* L.) under temperate conditions of Kashmir Valley. Int. J. Chemical studies 2020;8(4):2781-2784.
12. Manne H, Kumari N, Yashveer S, Nain S, Duhan J, Avtar R, Sushil, Jattan M, Rani B, Alshali AA and Ali S. Mitigation of lead toxicity in *Brassica juncea* L. by sulphur application – via various biochemical and transcriptomic strategies. Journal of King Saud University-Science 2024, 36(5): 103175
13. Manne HK, Kumari N, Sonia, Kodidhala V, Sushil, Avtar R, Jattan M, Rani B, Duhan J and Rati S. Natural Priming agents of plants to alleviate multiple stress tolerance. In: Exogenous priming and engineering of plant metabolic and regulatory genes. Academic press, Elsevier 2025, pp: 55-66
14. Marschner H. Mineral nutrition of higher plant, Second edition. London: Academic press 1995, 889.
15. Nain S, Kumari N, Manne HK, Sushil, Avtar R, Yashveer S, Malik K, Tokas J, Rathi S, Al-Anazi AA and Ahmad P. Impact of calcium on ascorbate-glutathione pool and gene expression under cadmium stress in Indian mustard (*Brassica juncea* L.). South African Journal of Botany 2025, 180: 12-20.
16. Pan M, Yau PC, Lee KC and Man HY. Effects of different fertilizers on the germination of tomatoand cucumber seeds. Water, Air, & Soil Pollution. 2022:Jan;233(1):25.
17. Pandey N. Role of micronutrients in reproductive physiology of plants. Plant Stress 2010;4(2):1-13.
18. Patel AK. Assessment of the effectiveness of MH and NAA on sex behaviour and yield of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] cv. Pattiwali. M.Sc. (Agri.) thesis submitted to Gujarat Agrl. University, S.K. Nagar 1992.
19. Patel AN, Parmar VK, Nayak SR and Patel NM. influence of pinching and plant regulators on morphological and sex expression of bottle gourd (*Lagenaria siceraria*). International Journal of chemical studies 2017;5(4):2035- 2038.
20. Rafeekher M, Gondane SU, Gormnagar HB, Murkute AA, Chaudhari DU and Patil RR. Hormonal regulation of growth, sex expression and yield of cucumber in kharif crops. J. Soils and Crops 2001;11(1):95-98.
21. Rai N, Yadav DS, Yadav RK and Patel RK. Response of paclobutrazol and maleic hydrazide on growth, flowering, fruiting and yield of bitter gourd cv. Meghalaya local. Ann. Agric. Res. New. Series 2003;24(1):64-67.
22. Sonia, Kumari N, Manne H, Jattan M, Rani B, Sushil, Ravika, Avtar R, Duhan J, Shweta and Sharma A. Insights in metabolomics responses to drought and salinity stress in crop plants. In: Kumar, A., Dhansu, P., Mann, A. (eds). Salinity and drought tolerance. Springer, Singapore. **2023**, 221-236
23. Thappa M, Kumar S and Romisa Rafiq. Influence of Plant Growth regulators on Morphological, Floral and yield Traits of Cucumber (*Cucumis sativus* L.) Kasetsart Journal Natural Science 2011;45:177-188.
24. Tyagi V. India’s agriculture: challenges for growth and development in present scenario. International journal of Physical and social Science 2012;2(5):116-128.
25. Sharma S, Sharma D, Thakur S, Katoch V, Kumari N and Lohia S. Plant growth regulators: their impact on cucurbits. Plant Archives Vol. 25, Supplement 1, 2025 pp. 963-970.
26. Santos RN and Guanzon IM.Different doses of ethephon enhanced the flowering and fruit yield component of the cucumber (*Cucumis sativus* L.). Journal of the Saudi Society of Agricultural Sciences,2024,