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Studies on influence of calcium and NAA to increase the productivity of Capsicum (*Capsicum annuum var. grossum*) cv. 'California Wonder'

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Abstract
The present investigation was carried out at Agricultural Research Farm, in the Department of Horticulture, School of Agriculture, at Suresh Gyan Vihar University, Jaipur (Rajasthan) during 2023-24. The experiment was laid out in Factorial Randomized Block Design which comprises of nine treatment combinations *viz;* Control (T_0), calcium @ 50 ppm (T_1), calcium @ 100 ppm (T_2), NAA @ 25 ppm (T_3), NAA @ 50 ppm (T_4), calcium @ 50 ppm + NAA @ 25 ppm (T_5), calcium @ 50 ppm + NAA @ 50 ppm (T_6), calcium @ 100 ppm + NAA @ 25 ppm (T_7), and calcium @ 100 ppm + NAA @ 50 ppm (T_8) treatments were replicated three times. The various concentrations of calcium and NAA had significant effect on various vegetative growth, yield and quality parameters and maximum (38.65 cm), (52.99 cm) and (73.55 cm) plant height, (8.86), (15.53) and (16.75) branches per plant and (47.59), (92.83) and (102.23) leaves per plant at 45, 60 and 75 DAT, respectively, minimum (39.13 days) took for 50% flowering, maximum (11.81) fruits per plant, highest (130.68 g) fruit weight, highest (1551.63 g/plant) and (43.10 t/ha) capsicum yield, maximum (131.51 mg/ 100 g) vitamin – C, net return (₹. 4, 02, 291.64/ha) and highest B: C ratio (4.31) were recorded under foliar application of calcium @ 100 ppm + NAA @ 25 ppm treatment.

Keywords: Capsicum, calcium, NAA and growth regulators

Introduction
Capsicum (*Capsicum annuum var. grossum*) commonly known as hot pepper, belongs to family solanaceae, having chromosome number 2n = 2x = 24 and is cultivated as an annual crop worldwide. The Portuguese introduced Capsicum from Brazil to India during 1584 and Christian missionaries introduced Capsicum species in the North-eastern states separately (Thamburaj and Singh, 2003) [21]. It is originated in Central America, most likely in Mexico (Vavilov, 1951) [22]. It is an excellent source of vitamin A and C. The pungency in chilli is due to an alkaloid capsaicin ($C_9Hi_4O_2$) which is a digestive stimulant. It contains high nutritive value with 1.29 mg/100 g protein, 11 mg/100 g calcium, 870 I.U vitamins-A, 175 mg ascorbic acid, 0.06 mg thiamine, mg riboflavin, 0.55 niacin per 100 g edible fruit and 321mg per 100 g of vitamin C (Agarwal *et al*., 2007) [1].

India is one of the largest producer, consumer and exporter of Chilli in the world, because of favourable soil and climatic conditions prevailing for Chilli production (Anonymous, 2021) [2]. India ranks first in area, and 2nd in production next to china. The total area under chilli cultivation is 4.26 million ha in the world with total production of 34.5 million tons (FAO, 2018). It is third most growing vegetable after tomato and potato (Naz *et al.,* 2006). India is accounting 7.43 lakh ha area and 19.14 lakh MT production with 2576 kg/ha productivity (NHB, 2022). In Rajasthan chilli is cultivated in 13812 ha area with production of about 13649 MT. The important chilli producing districts are Jodhpur, Alwar, Jaipur, Bhilwara, Tonk, Sawai Madhopur and Udaipur. Chilli is mainly used as culinary supplement to add flavour, colour, vitamin and pungency.

For commercial production of vegetable crops in many regions of the world, the use of growth regulators and Ca application can play an important role.

In general, there are significant economic losses of horticultural crops had been linked to inadequate calcium nutrition supply, or existing as unavailable form for absorption or immobile element and depends on transpiration rate. Calcium (Ca^{+2}) is an essential macronutrient for all higher plants. It is required for various structural roles in the cell wall and membranes and plays a key role in plant growth, fruit development. Also, it is involved in many biochemical and physiological processes in the plants which can improve yield (Marschner, 1995 and White and Broadley, 2003) [12, 23]. Successful cultivation of any crop depends in several factors. NAA has been reported to be useful for fruit formation, fruit thinning, abscission cell elongation, apical dominance, photoperiod and geotropism (Haidry *et al*., 1997) [8]. NAA application affects fruit formation through cell division and elongation (Dutta and Banik, 2007) [5].

Materials and Methods

The present study was conducted at Suresh Gyan Vihar University, Jaipur (Rajasthan) during *kharif* season of 2023. The geographical location of experimental site is 26º51' N latitude, 75º47' E longitudes and at altitudes of 390 m above mean sea level. The experimental area comes under semi-arid agro-climatic conditions. It has extremity of temperature both in summer (48.5 °C) and winter (-1 °C) and soil was sandy-loam with pH 7.2. The experiment was laid out in Randomized Block Design (Factorial) which comprises of nine treatment combinations *viz;* Control (T_0), calcium @ 50 ppm (T_1), calcium @ 100 ppm (T_2), NAA @ 25 ppm (T_3), NAA @ 50 ppm (T_4), calcium @ 50 ppm + NAA @ 25 ppm (T_5), calcium @ 50 ppm + NAA @ 50 ppm (T_6), calcium @ 100 ppm + NAA @ 25 ppm (T_7), and calcium @ 100 ppm + NAA @ 50 ppm (T_8) treatments were replicated three times. The capsicum cv. 'California Wonder' were used for study and transplanted on 8th July, 2023 by following 60 cm row to row and 45 cm plant to plant spacing. The crop was irrigated twice a week through drip irrigation and intercultural operations were done regularly as per the package and practices. The crop was foliar sprayed with calcium and NAA as per specified in treatments at 30 days after transplanting. All data were recorded from five randomly selected and tagged plants throughout the investigation and their mean value was calculated and statistically analyzed by OPSTAT software (Sheoran *et al.*, 1998) [18].

Results and Discussion

Growth Parameters

The foliar application of different concentration of calcium and NAA had significant impact and remarkable increase in growth and yield characteristics with the exogenous application of NAA and other growth hormones were also reported by earlier workers such as Bharti *et al*. (2020) [3] and Sobczak *et al.* (2024) [19]. Better vegetative growth of a crop is largely responsible for higher plant height because number of photosynthesizing sites i.e., number of vegetative branches is affected by initial growth stages. The significant increase in plant height was observed by all treatment combinations of the exogenous application of NAA growth regulators. Amongst the treatment, the maximum (38.65 cm), (52.99 cm) and (73.55 cm) plant height was recorded under foliar spray of calcium @ 100 ppm + NAA @ 100 ppm treatment folowed by (36.23 cm), (48.78 cm) and (67.81 cm) under foliar spray of NAA @ 50 ppm treatment at 45, 60 and 75 DAT, respectively. The calcium @ 100 ppm + NAA @ 100 ppm treatment were performed at par with NAA @ 50 ppm treatment (Table 1). This might be due to calcium is also important for proper cell division, cell elongation, and cell wall development. The increase in plant height is due to plant hormones promoted vegetative growth by active cell division, cell enlargement and cell elongation and thus helped in improving growth characteristics and also facilitated reproductive growth (Pareek *et al*., 2000) [17]. The maximum (8.86), (15.53) and (16.75) branches per plant were produced in foliar spray of calcium @ 100 ppm + NAA @ 25 ppm at 45, 60 and 75 DAT, respectively and it showed the significant effect over other concentrations and control. Similarly, the maximum (47.59), (92.83) and (102.23) leaves per plant at 45, 60 and 75 DAT, respectively were observed under foliar spray of calcium @ 100 ppm + NAA @ 50 ppm treatment followed by (46.10) and (99.49) under calcium @ 100 ppm + NAA @ 25 ppm at 45 and 75 DAT, respectively and performed significantly superior (Table 1). The increase in number of branches and leaves might be due to exogenous application of calcium and NAA that increases in cell wall plasticity and elongation in cell wall (Yugandhar *et al*., 2014) [24]. The increase in number of branches and leaves per plant might be due to application of NAA which enhances the lateral buds and branches, leaves, breaking apical dominance and vegetative growth Bijalwan *et al.* (2022) [4].

Flowering and Fruit Set:

Fruit set increased dramatically with the spraying of NAA in capsicum (Bijalwan *et al.*, 2022) [4]. Fruit set is a critical stage in the conversion of a flower into a fruit in order to get a high yield and maximize a grower's profits. The interaction effect of calcium and NAA also had significantly reduced the number of days to 50% flowering and first harvesting. The minimum (39.13 days) took for 50% flowering and (47.72 days) took for first harvesting under foliar spray of calcium @ 100 ppm + NAA @ 50 ppm treatment (Table 1). It might be due to NAA reduced fruit abscission. The similar results were also reported by Naga *et al.* (2022) [14] and Hariom and Topno (2023) [9].

It is evident from the data presented in Table 2 revealed that the interaction of calcium and NAA also had significant effect on number of fruits per plant and the maximum (11.81) fruits per plant were recorded under foliar spray of calcium @ 100 ppm + NAA @ 25 ppm treatment (Table 2). Spraying of calcium and NAA was found to be effective in reducing premature fruit drop (Naga *et al.* (2022) [14]. It might be due maximum fruit set, minimum fruit drop and maximum fruit retention by NAA treatment that ultimately increases the number of fruits per plant. It may also be foliar spray of secondary macronutrient that promotes the production of more photosynthesis required for good number of capsicum fruits. Both calcium and NAA works synergistically. Similar results were also reported by Bijalwan *et al.* (2022) [4] and Naga *et al.* (2022) [14].

Yield Attributing Parameters

The combined effect of calcium and NAA resulted in a considerable increase in fruit length, diameter, weight and volume (Kaur *et al.*, 2016) [10]. The role of calcium in improving fruit quantity namely, fruit weight and fruit size may be due to its role in increasing cell elongation and cell division (Eman *et al*., 2007) [6]. The maximum (6.92 cm) fruit length was observed under foliar spray of calcium @ 100 ppm treatment followed by (6.48 cm) under calcium @ 50 ppm treatment. In foliar spray of NAA, the maximum (6.93 cm) fruit length was recorded under NAA @ 50 ppm followed by (6.77 cm) fruit length under NAA @ 25 ppm treatment (Table 2). These results are in close

conformity with the findings of Mayorga-Gómez *et al.* (2020) [13]; Naga *et al*. (2022) [14] and Hariom and Topno *et al*. (2023) [9]. The greatest (5.71 cm) fruit diameter was recorded under foliar spray of calcium @ 100 ppm treatment followed by (5.26 cm) under calcium @ 50 ppm treatment whereas, in foliar application of NAA, the maximum (5.71 cm) fruit diameter was observed under NAA @ 50 ppm followed by (5.55 cm) under NAA @ 25 ppm treatment (Table 2). It might be due to additional supply of calcium that increases in cell wall plasticity and elongation in cell wall (Yugandhar *et al*., 2014) [24].

The highest (130.68 g) fruit weight was recorded in foliar spray of calcium @ 100 ppm + NAA @ 25 ppm treatment. Hence, calcium @ 100 ppm + NAA @ 25 ppm treatment performed significantly superior over foliar spray of different concentrations. Whereas, the lowest (72.38 g) fruit weight was recorded under water sprayed plants (Table 2). This might be due to synergistic effect of calcium and NAA that promotes cell elongation, enlargement of vacuoles and loosening of cell wall after increasing cell wall plasticity. These results are in close conformity with the findings of Tapdiya *et al.* (2018) [20], Bijalwan *et al.* (2022) [4] and Naga *et al.* (2022) [14].

Yield Parameters

Among the different concentrations of calcium and NAA, the highest (1551.63 g/plant) and (43.10 t/ha) capsicum fruit yield was recorded in foliar spray of calcium @ 100 ppm + NAA @ 25 ppm treatment followed by (32.67 t/ha) under calcium @ 100 ppm + NAA @ 50 ppm treatment presented in Table 2. This might be due to exogenous application of calcium and NAA that increases in cell wall plasticity and elongation in cell wall (Yugandhar *et al*., 2014) [24]. The fruit length, fruit diameter, fruit weight and number of fruits per plant cumulatively increases the capsicum yield. These results are in close conformity with the findings of Mayorga-Gómez *et al.* (2020) [13] and Hariom and Topno (2023) [9].

Quality Parameters

The interaction of calcium and NAA had significant effect on vitamin-C content in capsicum. The highest (131.51 mg/ 100 g) vitamin - C was recorded in foliar spray of calcium @ 100 ppm + NAA @ 25 ppm treatment, whereas, the minimum (92.07 mg/ 100 g) vitamin –C was recorded under water sprayed control (Table 2). The ascorbic acid content consistently increased with application of calcium and NAA that works synergistically and plays key role in metabolic activities, where calcium delays rapid oxidation of ascorbic acid. These results are in close conformity with the findings of Khan and Ali (2016) [11] and Bijalwan *et al.* (2022) [4].

Economic Parameters

The maximum net return (₹. 4, 02, 291.64/ha) and highest B: C ratio (4.31) of capsicum production was recorded under calcium @ 100 ppm + NAA @ 50 ppm (Table 2). This might be due to exogenous application of calcium and NAA that increases fruit length, fruit weight and number of fruits that ultimately increased the yield per plant as well as per hectare. These results are in close conformity with the findings of Tapdiya *et al.* (2018) [20] and Bijalwan *et al.* (2022) [4].

Conclusions

The foliar application of calcium @ 100 ppm + NAA @ 50 ppm treatment was found significantly superior treatment over all the treatments on vegetative growth, yield attributing, yield and quality characteristics of capsicum.

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Conflict of Interest

The authors declare that there is no conflict of interest among all co-authors.

Ethical Statement

This article does not contain any studies with human participants or animals performed by any of the author.

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