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Effect of plant growth regulators on growth and seed yield of onion

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Abstract
Onion is an important vegetable crop grown in almost all parts of the world as a flavouring agent in food preparation. It is propagated by bulb or seeds. The field experiment was carried out during 2023-24 at Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Presence study aimed to find out the effect of different plant growth regulators on growth and seeds yield of onion at different concentration-Ethephon (100 & 200 ppm), Cycocel (100 & 200 ppm), Paclobutrazol (100 & 200 ppm) and Brassinosteroid (0.5 &1 ppm) on onion (*Allium cepa* L.). Two foliar sprays of these plant growth regulators are given at seed scape emergence stage and flower initiation after planting of bulbs. The statistical design adopted for experiment was randomized block design (RBD) with three replications and nine treatments. The observation recorded for vegetative growth in terms of Plant height, number of leaves per plant, number of seed stalks per plant, number of primary umbels per plant, number of secondary umbels per plant, yield parameters *viz*. flowers per primary and secondary umbels, seed weight of primary and secondary umbels, yield per plant, yield per plot, and yield per hectare, post harvest parameters *viz*. 1000 seed weight of primary and secondary umbel, germination percentage of seed of primary and secondary umbel were observed. The results showed that 200 ppm CCC significantly reduced the plant height and increased number of leaves, and number of seed stalks, number of primary and secondary umbels were found with Ethephon 200 ppm. The Ethephon application also significantly improved flowers per umbels, seed weight per primary and secondary umbel, yield per plant, yield per plot, yield per heactare, 100 seed weight of primary umbel, germination% of primary and secdondary umbel were recorded with ethephon 200 ppm. Hence, foliar spray with ethephon 200 ppm followed by CCC 200 ppm were found to be effective in improving the seed yield and seed quality in onion.

Keywords: Onion, plant growth regulators, Ethephon, CCC, seed yield, seed quality, germination

Introduction
Onion (*Allium cepa* L.), the most common member of the family *Alliaceae*, is believed to be native to Asia and possibly introduced from Palestine to India. It is cultivated widely as an herbaceous, biennial vegetable crop with cross-pollinated, monocotyledonous characteristics and a diploid chromosome number of 2n = 16. Onions are an important cash crop, harvested both in the green stage and as mature bulbs. They also contain a volatile oil, primarily *allyl-propyl disulphide*, which is responsible for their distinctive pungency.

As onion is extensively cultivated, there is a constant and high demand for fresh seed each year. Seed is one of the most crucial inputs in agriculture—its quality significantly influences the efficiency of other agricultural and horticultural practices. Onion growth and seed production are sensitive to temperature and photoperiod, making the timing of planting a decisive factor in achieving good quality seed yield.

Flowering and seed formation occur in late spring or early summer, triggered by a vernalization period during winter. The onion inflorescence, an umbel, can produce anywhere from 50 to 2,000 flowers. Due to its composition of smaller, 5-10 flowered cymes, flowering is prolonged—lasting up to two weeks—and occurs unevenly. Plants grown from bulbs typically produce more flower stalks than those grown from seed.

For ensuring pure, true-to-type seed production, it is vital to standardize onion seed production techniques. Factors such as variety, plant spacing, mother bulb size, production method, environmental conditions and application of plant growth regulators has significantly altered the growth and production of numerous vegetable crops. The vital role played by different plant growth regulators as paclobutrazol, cycocel, brassinosterroid and ethrel in changing the growth behavior of plants resulting in term of vegetative growth, maximum number of umbel, and finally increased seed yield. The use of these growth regulators substances has huge scope to use in onion crop because of its easy application and comparatively bigger advantages.

Besides the huge scope for the use of growth regulators there are some limitations like lack of knowledge about the practical utility of growth regulators, and thereby which results in limited use by the growers. The adverse effect of growth regulators on the many crop also noticed if the appropriate concentration are not used at right time. Moreover, ignorance of growers about use of growth regulators are the limitations on the utilization of growth regulators. Besides this manual weeding is time consuming and labour intensive work, Too much fluctuation in prices of seed, High cost of seed, Non availability of seed and planting materials in time, Non availability of fertilizer in time. Therefore, The present investigation might be helpful to find out the suitable and useful plant growth regulators with its proper concentration on growth, Seed yield and quality.

Material and Methods

The present investigation entitled “Effect of plant growth regulators on growth, seed yield and quality of onion” was carried out at the instructional farm of the Department of Vegetable Science, Dr. PDKV Akola, during the *Rabi* season of 2023-24.

Planting Material: The bulbs of onion variety, Akola safed were obtained from Department of Vegetable Science, Dr. PDKV, Akola. The bulb of uniform size and shape were selected and planted at 60 × 30 cm.

The experiment followed a randomized block design (RBD) with nine treatment combinations of plant growth regulators. The treatments included Ethephon 100 ppm (T_1), Ethephon 200 ppm (T_2), Cycocel 100 ppm (T_3), Cycocel 200 ppm (T_4), Paclobutrazol 100 ppm (T_5), Paclobutrazol 200 ppm (T_6) Brassinosteroid 0.5 ppm (T_7), Brassinosteroid 1 ppm (T_8) and Control (T_9). Each treatment was replicated three times.

Growth regulator solutions were prepared and applied as foliar sprays at two stages—At seed scape emergence stage and At flower stalk inition stage. Growth, yield and quality parameters were assessed by randomly selecting five plants from each treatment plot.

The selected data were statistically analyzed by Panse and Sukhatme (1967) [10]. The standard error and critical difference at a 5% significance level were computed to evaluate the differences between treatment means.

Results and Discussion

Plant height (cm)

The data regarding plant height as influenced by application of plant growth regulators were recorded and presented in table 1. At harvest, minimum (70.10 cm) plant height was recorded with application of cycocel at 200 ppm (T_4), followed by paclobutrazol 200 ppm (72.00 cm). However, maximum (81.22 cm) plant height was recorded in control (T_9), which was followed by treatment brassinosteroid 1 ppm (76.50 cm). The reason for reduction in height of plant might be due to, growth regulators CCC prevents the activities of synthesized anti-covering enzyme and decreases the plant height and increases the vertical growth of branches so that the plant receives much light to do photosynthesis (Helaly *et al*. 2016) [8].

Number of leaves plant^{-1}

The application of plant growth regulators had a significant effect on the number of leaves per plant were recorded and presented in table 1. Among the treatments, the maximum (40.70) number of leaves were recorded in cycocel at 200 ppm (T_4). which was followed by treatment cycocel 100 ppm (38.67). However minimum (30.83) number of leaves were recorded with application of paclobutrazol 100 ppm (T_5). Foliar application of different growth regulators significantly increase number of leaves in onion. This effect is due to Cycocel (Chlormequat chloride) acting as a gibberellin biosynthesis inhibitor, modifies hormonal balance, particularly reducing gibberellins, thus increasing foliage density and leaf number, reduces stem elongation and promotes leaf initiation by enhancing cell division in meristematic tissues and reducing apical dominance. These findings are supported by (Rademacher 2000) [11].

Number of seed stalks per plant

The data in respect of number of seed stalks per plant influenced by application of plant growth regulators were recorded and presented in table 1. Data indicated the significant effect on the number of seed stalks per plant. Significantly maximum (9.43) number of seed stalks per plant were recorded with application of ethephon 200 ppm T_2, it was found statistically at par with treatment (T_3) and T_4 (8.90), treatment T_1 ethephon 100 ppm (8.67), paclobutrazol 200 ppm T_6 (8.57). However, minimum number of seed stalks (7.38) were recorded, without any application of growth regulators (T_9) in onion. The reason for increase in number of seed stalks might be due to, According to El-Khallal *et al*. (2009) [6] did observe that Ethephon treatment in onion led to enhanced flowering and improved seed stalk development.

Number of primary umbels per plant

The data regarding the number of primary umbels per plant as influenced by different application of plant growth regulators were recorded and presented in table 1. Significantly the maximum (6.80) number of seed stalks per plant were recorded with application of ethephon 200 ppm (T_2). This treatment was followed by cycocel 200 ppm (T_4). Whereas, the minimum (5.51) number of primary umbels per plant were recorded in treatment (T_9) without any application of growth regulators. The higher number of primary umbels per plant with ethephon 200 ppm application may be due to ethylene release, which suppresses apical dominance, promotes lateral meristem activation, and enhances flowering initiation, resulting in more seed stalk formation.

Number of secondary umbels per plant

The data regarding the number of secondary umbels per plant as influenced by different application of plant growth regulators were recorded and presented in table 1. Significantly the maximum (2.63) number of secondary umbels were produced in the treatment T_2 (ethephon 200 ppm). followed by cycocel 200 ppm (T_4). However, minimum number of secondary umbels per plant (1.80) was recorded in treatment brassinosteroid 0.5 ppm (T_7). The increased number of umbels may be attributed to suppression of apical dominance, activating multiple meristems and increasing branching, as reported by Deepak *et al*. (2007) [5] in okra and Rafeekher *et al*. (2001) [12] in cucumber. Ethephon (up to 960 ppm) further promotes flowering and seed set through its growth-retarding effect on seed stalks or direct influence on reproductive processes (Arteca, 1995) [2].

Yield Parameters

Flowers per primary umbel

The data regarding flowers per primary umbels as influenced by different plant growth regulators were recorded and presented in table 2. The data depicted in Table 2 clearly indicated that, Significantly the maximum (655.80) flowers per primary umbel were recorded with application of paclobutrazol 100 ppm (T_5). which was at par with ethephon 200 ppm T_2 i.e. (655.08), cycocel 200 ppm T_4 (634.27). However, the minimum flowers per primary umbel (538.57) were recorded in treatment T_8.

The reason for increased in flowers per primary umbel might be due to that, Paclobutrazol was found to be the most effective treatment in enhancing the number of flowers per primary umbel, recording 655.80 flowers, which was significantly superior to most other treatments. This effect is likely due to its gibberellin-inhibiting action that restricts vegetative growth and reallocates resources to reproductive development, thereby increasing floral initiation and retention (Rademacher 2000, Davis *et al*. 1988, Steffens *et al*. 1985) [11, 4, 14].

Flowers per secondary umbel

The data regarding flowers per secondary umbels as influenced by different plant growth regulators were recorded and presented in table 2. The data depicted in Table 2 clearly indicated that, Significantly the maximum (512.97) flowers per secondary umbel were recorded in the treatment T_2 (ethephon 200 ppm). Which was at par with (501.13) with treatment T_4 (cycocel 200 ppm), T_3 (cycocel 100 ppm), T_5 (paclobutrazol 100 ppm). However, the minimum flowers per secondary umbel (425.63) were recorded in treatment T_6 (paclobutrazol 200 ppm). Different plant growth regulators significantly influenced the number of flowers per secondary umbel ion onion. The increased in floral count under certain treatments, particularly with ethylene-releasing compounds, may be due to enhanced floral initiation, suppression of apical dominance, and more effective allocation of assimilates to floral meristems. These physiological mechanisms contribute to the promotion of flower development. This effects have been reported by (Arteca & Arteca 2000, Salisbury & Ross 1992, and Abdel-Mawgoud *et al*. 2010) [3, 13, 1].

Table 1: Effect of plant growth regulators on plant height (cm), number of leaves per plant, number of seed stalk per plant, number of primary umbel per plant and Number of secondary umbel per plant.

Treatments	Plant height (cm)	Number of leaves per plant	Number of seed stalk per plant	Number of primary umbels per plants	Number of secondary umbels per plants
T_1 (Ethephon 100 ppm)	74.70	36.53	8.67	6.43	2.17
T_2 (Ethephon 200 ppm)	72.11	32.80	9.43	6.80	2.63
T_3 (Cycocel 100 ppm)	73.20	38.67	8.90	6.47	2.43
T_4 (Cycocel 200 ppm)	70.10	40.70	8.90	6.50	2.40
T_5 (Paclobutrazol 100 ppm)	71.90	31.43	7.47	5.58	1.89
T_6 (Paclobutrazol 200 ppm)	72.00	30.83	8.57	6.24	2.33
T_7 (Brassinosteroid 0.5ppm)	74.00	36.20	8.00	6.20	1.80
T_8 (Brassinosteroid 1 ppm)	76.50	34.57	8.38	6.31	2.07
T_9 (Control)	81.22	34.60	7.38	5.51	1.87
F test	Sig	Sig	Sig	Sig	Sig
SE(m)±	1.19	0.74	0.34	0.06	0.06
CD at 5%	3.48	2.15	1.00	0.17	0.17

Table 2: Effect of plant growth regulators on yield and yield contributing characters of onion.

Treatments	Flowers per primary umbel	Flowers per secondary umbel	Seed weight of primary umbel(g)	Seed weight of secondary umbel (g)	Seed yield per plant (g)	Seed yield per plot(kg)	Seed yield per quintal (q/ha)
T_1 (Ethephon 100 ppm)	595.73	484.40	11.68	4.71	16.40	2.00	8.87
T_2 (Ethephon 200 ppm)	655.08	512.97	12.85	5.21	18.06	2.27	10.07
T_3 (Cycocel 100 ppm)	621.20	498.47	11.99	4.67	16.66	2.14	9.52
T_4 (Cycocel 200 ppm)	634.27	501.13	12.41	4.80	17.21	2.18	9.55
T_5 (Paclobutrazol 100 ppm)	655.80	500.13	10.60	4.15	14.72	1.84	8.16
T_6 (Paclobutrazol 200 ppm)	561.80	425.63	10.13	3.69	13.82	1.72	7.65
T_7 (Brassinosteroid 0.5ppm)	553.00	449.33	10.73	4.14	14.87	1.86	8.22
T_8 (Brassinosteroid 1 ppm)	538.57	446.43	10.40	3.92	14.32	1.79	7.94
T_9 (Control)	621.00	447.20	9.12	3.75	12.87	1.64	7.29
F test	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SE(m)±	10.78	4.97	0.33	0.15	0.40	0.05	0.22
CD at 5%	31.76	14.52	0.97	0.44	1.17	0.14	0.65

Table 3: Effect of plant growth regulators on test weight (g) and germination of onion seed (%).

Treatments	1000 Seed weight of primary umbel (g)	1000 Seed weight of secondary umbel (g)	Germination% of seed of primary umbel	Germination% of seed of secondary umbel
T_1 (Ethephon 100 ppm)	3.94	3.80	89.47	83.67
T_2 (Ethephon 200 ppm)	4.06	4.10	94.33	94.16
T_3 (Cycocel 100 ppm)	3.83	3.63	88.23	88.70
T_4 (Cycocel 200 ppm)	4.00	4.20	91.32	92.87
T_5 (Paclobutrazol 100 ppm)	3.80	3.67	88.00	87.50
T_6 (Paclobutrazol 200 ppm)	3.80	3.57	84.63	83.53
T_7 (Brassinosteroid 0.5ppm)	3.80	3.93	90.86	91.03
T_8 (Brassinosteroid 1 ppm)	3.90	3.70	90.48	90.77
T_9 (Control)	3.73	3.60	81.10	85.10
F test	Sig	Sig	Sig	Sig
SE(m)±	0.06	0.05	1.60	2.14
CD at 5%	0.18	0.16	4.67	6.24

Seed weight of primary umbel per plant (g)

The data regarding seed weight of primary umbel per plant was recorded and presented in table 2. The highest seed weight of primary umbel per plant (12.85g) was observed with T_2 (ethephon 200 ppm). This treatment was found at par with T_4 (cycocel 200 ppm) T_3(cycocel 100 ppm). However, minimum seed weight per primary umbel (9.12 g) was recorded in T_9 (control). The increased seed weight per primary umbel may be due to ethylene-induced flower retention, improved pollination and fertilization, and enhanced assimilate flow for better seed filling (Arteca & Arteca, 2000; Salisbury & Ross, 1992; Abdel-Mawgoud *et al*., 2010) [3, 13, 1].

Seed weight of secondary umbel per plant (g)

The data regarding seed weight of secondary umbel per plant was recorded and presented in table 2. The highest seed weight of secondary umbel per plant (5.21 g) was recorded with application of treatment T_2 (ethephon 200 ppm). which was followed by T_4 cycocel 200 ppm (4.80 g). However, the minimum seed weight per secondary umbel (3.69g) which found in treatment T_6 (paclobutrazol 200 ppm) which was at par with control T_9 (3.75 g), T_8 brassinosteroid 1ppm (3.92 g). The reason for increased in seed weight per secondary umbel in plant might be attributed to In secondary umbels, the higher seed weight may be due to better flower retention, improved pollination and fertilization, and increased nutrient flow to developing seeds, leading to enhanced seed filling.

Seed yield per plant (g)

The data related to yield per plant as influenced due to application of different plant growth regulators are presented in table 2. The data presented in table 2, revealed that, Significantly the maximum (18.06 g) seed yield per plant was recorded from the treatment T_2 (ethephon 200 ppm). This treatment was followed by treatment T_4 (cycocel 200 ppm). However, minimum seed yield per plant (12.87 g) was recorded in T_9 (control). This increase in seed yield may be due to enhanced flowering, better seed setting, and efficient assimilate partitioning towards seed development.

Seed yield per plot (kg)

The data related to yield per plot as influenced due to application of different plant growth regulators are presented in table 2. The data presented in table 2, revealed that, Significantly the maximum (2.27 kg) seed yield per plot was recorded in treatment T_2 (ethephon 200 ppm). Which was at par with T_4 (cycocel 200 ppm). and T_3 (cycocel 100 ppm). However, the minimum seed yield per plot was recorded in treatment T_9 (control). The higher seed yield per plot could be due to stimulated reproductive growth, prolonged flowering period, and enhanced seed filling efficiency.

Seed yield per hectare (q)

The data in respect of seed yield per hectare was recorded at harvest stage is presented in Table 20 and graphically depicted in Fig 21. Significantly the maximum (10.07 q) seed yield per hectare was recorded with application of treatment T_2 (ethephon 200 ppm). which was at par with treatment T_4 (cycocel 200 ppm) i.e. (9.55 q) and T_3 (cycocel 100 ppm) However, the minimum seed yield per hectare was recorded in T_9 (control) without use of plant growth regulators. The reason for increased in seed yield might be attributed due to Ethephon 200 ppm was most effective because it releases ethylene, which promotes early and synchronized flowering, enhances floral meristem development, and improves seed set and filling by redirecting assimilates toward reproductive organs through the suppression of apical dominance (Arteca & Arteca, 2000) [3]. These physiological effects lead to significantly higher seed yield also reported by Kumar *et al*. (2014) [9] and Yadav *et al*. (2005) [15].

Post Harvest Parameters

1000 Seed weight (Test weight) of primary umbel (g)

The data regarding the test weight of primary umbel as influenced by different application of plant growth regulators was noticed and presented in table 3. The data depicted in Table 3 revealed that, Significantly the maximum test weight (4.06 g) was recorded in treatment T_2 with (ethephon 200 ppm). which was statistically at par with treatments T_4 (4.00 g), T_1 (ethephon 100 ppm). and T_8 (brassinosteroid 1ppm). However, the minimum (3.73 g) test weight was recorded in T_9 (control) without application of growth regulators.

The test weight of onion seeds was significantly influenced by the application of plant growth regulators particularly of ethephon, resulted in higher 1000 seed weight compared to the control. This may be due to enhanced flowering, better seed setting, and efficient assimilate partitioning induced by ethylene released from Ethephon, as reported by (Kumar *et al*. 2014) [9]. Faster assimilate translocation during seed filling and maturation likely contributed to increased seed weight. Similar results was observed by (Hameed 2004) [7] in okra.

1000 Seed weight (Test weight) of secondary umbel (g)
The data regarding the test weight of secondary umbel as influenced by different application of plant growth regulators was noticed and presented in table 3. The data depicted in Table 3 revealed that, The maximum (4.20g) test weight was recorded with application of growth regulators cycocel at the concentration of 200 ppm (T_4). It was followed by treatments T_2 ethephon 200 ppm (4.10 g). However, the minimum (3.57 g) test weight was recorded in T_6 (paclobutrazol 200 ppm). The test weight of onion seeds was significantly influenced by the application of plant growth regulators may be due to its gibberellin-inhibiting effect, which reduces excessive vegetative growth and directs more assimilates to reproductive organs, thereby enhancing seed filling (Rademacher, 2000) [11].

Germination percentage of seed of primary umbel (%)
The data in respect to germination% of primary umbel was recorded and presented in table 3. The data depicted in table 3, indicated that, The maximum (94.33%) germination percentage was recorded in treatment T_2 (ethephon 200 ppm). which was statistically at par with treatments T_4 (cycocel 200 ppm), T_7 (brassinosteroid 0.5 ppm) and T_8 (brassinosteroid 1ppm). However, the minimum (81.10%) germination percentage was recorded in T_9 (control). The highest germination percentage may be due to better seed development, enhanced physiological maturity, and improved seed vigor, resulting in higher viability.

Germination percentage of seed of secondary umbel (%)
The data in respect to germination% of secondary umbel was recorded and presented in table 3. The data depicted in table 3, indicated that, The maximum (94.16%) germination percentage was recorded in treatment T_2 (ethephon 200 ppm). which was statistically at par with treatments (T_4) cycocel 200 ppm, brassinosteroid 0.5 ppm and (brassinosteroid 1 ppm). However, the minimum (83.53%) germination percentage was recorded in treatment T_6 (paclobutrazol 200 ppm). Improved germination may be due to ethylene released from ethephon, which enhances assimilate partitioning, promotes uniform seed filling, and accelerates maturation, resulting in physiologically active seeds with higher viability (Arteca & Arteca, 2000; Kumar *et al*., 2014; Hameed, 2004) [3, 9, 7].

Conclusions
Based on the findings of the present investigation, it can be concluded that foliar application of plant growth regulators significantly enhances growth, seed yield, and post-harvest parameters in onion. Among the treatments, Ethephon 200 ppm proved to be the most effective, as it improved flowering, enhanced seed setting, and contributed to higher seed yield and better post-harvest seed quality. Cycocel 200 ppm also showed promising results by promoting vegetative growth and supporting yield attributes. These findings suggest that the judicious use of growth regulators, particularly Ethephon and Cycocel, can be a valuable strategy to improve seed production and overall productivity in onion.

Future Scope
This study investigates the role of plant growth regulators, optimizing PGR dose and timing, studying varietal responses, integrating with nutrient and water management, exploring physiological mechanisms, assessing seed storage quality, ensuring environmental safety, and validating economic feasibility through multi-location trials.

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