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Research Paper

Effect of growth regulators on growth, yield and storage life of *Kharif* onion (*Allium cepa*)

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ABSTRACT

A field investigation involving pre-harvest sprays of different growth-regulators such as cycocel, salicylic acid and etheral, and plant protectants like mancozeb, carbendazim and streptocyclin, was carried out during the rainy (*kharif*) seasons of 2018–19 and 2019–20 at Neri, Hamirpur, Himachal Pradesh to study their effect on production and storage of *kharif* onion (*Allium cepa* L.) variety 'Agrifound Dark Red'. Application of salicylic acid @ 100 ppm followed by cycocel @ 2,500 ppm significantly enhanced the crop growth, yield and reduced various storage losses, viz. physiological loss in weight, diameter, sprouting and rotting during 90 days storage period.

Key words: Cycocel, Growth regulators, *Kharif* onion productivity, Salicylic acid, Storage life

India is the second largest producer of onion after China, with an area of 1,293 thousand ha and production 21,718 thousand MT. In Himachal Pradesh, area and production of onion is around 2.56 thousand ha and 48.53 thousand million tonnes (NHB, 2019). Onion is produced in 3 seasons, i.e. rainy season (*kharif*), winter (*rabi*) and late *kharif* in our country. Sixty per cent production comes from *rabi* season crop while *kharif* and late *kharif* crops contribute 20% each. The rabi season crop of onion is harvested in April–May, while *kharif* onion and late *kharif* crop of onion are available in the market in October–December and January–February respectively. The *kharif* onion is produced in parts of Maharashtra, Gujarat, Karnataka and Rajasthan. The major portion of *rabi* season crop is stored throughout the country which is available for domestic markets as well as for export from May to October. Short supply of onion from October to December results in country shoot up of prices in country. The *kharif* crop can play an important role in fulfilling consumer's demand and stabilizing the prices of onion in the country. So *kharif* onion, is most crucial in controlling market prices vis-a-vis making available onions to consumers. Poor shelf-life and frequent weed growth are the major limitations in *kharif* onion production. Yield losses in *kharif* onion due to weed infestation is high (40–80%) which can be effectively controlled with appropriate combination of cultural and chemical weed management practices (Chopra and Chopra, 2007; Patel *et al.,* 2011). *Kharif* onion is a delicate commodity to store because of higher water content and serious losses occur due to rotting, sprouting, physiological loss in weight and moisture evaporation, resulting in 50–90% storage losses depending on genotype and storage conditions (Shivakumar, 2014). Storage is one of the most important aspects for post-harvest handling of *kharif* onion, as around 35 to 40% of onion is lost in India annually during post-harvest handling and storage. Yield and quality of onion is highly influenced by application of nutrients. Bulb pungency increased by application of potassium as reported by Singh and Verma (2001). Application of plant-growth regulators and fungicides could be employed as pre-harvest foliar sprays to extend the shelf-life and reduce spoilage in onion, as more scientific understanding of their action is known today. As application of these synthetic growth-regulators is known to affect the internal levels of the naturally occurring hormones, resulting in modification of growth and development in the desired direction and to the desired extent. Salicylic acid (SA) is a phenolic phytohormone that acts as a key regulator of the signaling network in plants under abiotic and biotic stresses. Cycocel is one of the most extensively used plant-growth retardants to control the vegetative growth of

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the plants and thereby enhances the production of a number of agricultural and horticultural crops. Reduction in leaf number and leaf area was reported due to cycocel application in several crop plants (Kumar *et al.,* 2017). Exogenous ethylene proved to be a powerful inhibitor of sprout growth in onion bulbs. The dormancy breaking effect of 1-MCP indicates a regulatory role of endogenous ethylene in onion bulb dormancy. Exogenous ethylene suppressed sprout growth of both dormant and already sprouting onion bulbs by inhibiting leaf-blade elongation. Streptocyclin is a bactericide, enhances storage life by controlling bacterial diseases. Bacterial brown rot (*Pseudomonas aeruginosa*) is very serious disease of onions in storage. The infection occurs through the wounds. The rot begins at the neck of the bulbs which later gives foul smell through the neck when squeezed. If rains occur during maturity, spraying of streptocycline (0.02%) is recommended.

Onion suffers from many diseases from pre-harvest to post-harvest period. About 35–40% onion is lost due to damage caused by different diseases. Fungi are the main causal agent responsible for pre-and post-harvest period losses in the onion. Carbendazim and mancozeb inhibit bulb rotting by preventing them from fungal rotting. Losses of onion during storage are considerable mainly due to sprouting and contamination by several micro organisms. Nearly 40% of the production is lost during post-harvest handling and storage. Microbial spoilage during storage alone contributes approximately 15–20% of the total loss and *Aspergillus niger* alone causes as high as 80% spoilage. Based on this concept, growth regulators like cycocel (CCC), salicylic acid, ethylene; fungicides like mancozeb, carbendazim, and bactericide, i.e. streptocyclin, were applied in the field to check their efficacy in storage on various parameters like per cent weight loss, per cent loss in bulb diameter, black mould percentage, rotting percentage, sprouting percentage.

MATERIALS AND METHODS

The experiment was conducted at Vegetable Farm of College of Horticulture and Forestry, Neri, Hamirpur of the Dr Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh during 2018–19 and 2019–20 in *kharif* season on (*Allium cepa* L.) 'Agrifound Dark Red' onion. The experimental site falls under low-hill region of Himachal Pradesh and is located at an altitude of 620 m above mean sea level with average mean maximum and minimum temperature levels of 31.3°C and 12.4°C, respectively. The experiment was laid out in randomized block design with 13 treatments and 3 replications, viz. T_1, salicylic acid 50 ppm; T_2, salicylic acid 100 ppm; T_3, salicylic acid 150 ppm; T_4, cycocel 1,500 ppm; T_5, cycocel 2,000 ppm; T_6, cycocel 2,500 ppm; T_7, etheral 1,000 ppm; T_8, etheral 2,000 ppm; T_9, etheral 3,000 ppm; T_{10}, mancozeb (2.5g/litre); T_{11}, carbendazim (1g/litre); T_{12}, streptocyclin (500 ppm); and T_{13}, control. The crop was raised through sets of 1.5–2.0 cm size because successful nursery raising and transplanting during rainy season is a problem for growing *kharif* season crop due to prevalence of soil-borne pathogens. However, it is possible to raise *kharif* onion crop successfully through onion sets. During mid of August onion sets were replanted in the main field with the plot size of 1.5 m × 1.5 m at a spacing of 15 cm × 10 cm. Salicylic acid sprayed twice at 30 days and 90 days after replanting of sets. Cycocel was sprayed 90 days after planting and etheral was sprayed 2 weeks prior to harvesting. Mancozeb and carbendazim were sprayed thrice at 1 month interval. Streptocyclin was sprayed a week prior to harvesting. The bulbs were harvested when more than 50% plants turned yellow and harvested bulbs were well cured and kept in plastic baskets and then subjected to prolonged storage of 3 months. Data were recorded for various growth parameters like number of leaves, plant height (cm), polar bulb diameter (cm) equatorial bulb diameter (cm), bulb weight (g) at full growth stage by selecting 10 plants/plot randomly, whereas bulb yield/plot (kg) and yield/ha (q) were recorded at the time of harvesting. Various storage losses such as per cent weight loss, per cent loss in bulb diameter, black mould percentage, rotting percentage, sprouting percentage were recorded during storage at 15 days intervals up to 3 months. Fresh weight loss was determined by the weight of the bulbs on 0 (initial weight), and 15 days interval for 3 months of storage period using an electronic balance as per following formula: Fresh mass loss percentage= $[(P_0–P_n)/P_0]\times100$

Where P_0 is initial weight and P_n is n^{th} days weight. percent loss in bulb diameter was also calculated by measuring initial and final bulb diameter with vernier caliper and then using the following formula:

where D_0 is initial diameter and D_n is n^{th} days diameter.

$$\text{Loss in bulb diameter (\%)} = \frac{[(D_0 - D_n)]}{D_0} \times 100$$

Sprouted, black mould infected and rotted bulbs were counted separately in each treatment combination with interval of 15 days for 3 months and divided by the total number of bulbs then multiply by 100 to calculate sprouted and rotted bulb percentage. The data for all characters were analysed using the analysis of variance (Panse and Sukhatme, 1989).

RESULTS AND DISCUSSION

Growth traits

The results pertaining effect of different treatments on growth and yield of *kharif* onion are presented in Table 1. Significant variations were noticed among all the traits due

Table 1. Effect of growth-regulators on growth and yield parameters of rainy-season onion

Treatment	Number of leaves	Plant height (cm)	Bulb diameter (cm) Polar	Bulb diameter (cm) Equatorial	Bulb weight (g)	Bulb yield per plot (kg)	Bulb yield per hectare (q/ha)	Bolting (%)	Doubles (%)	TSS (° Brix)
T_1, Salicylic acid 50 ppm	7.27	57.23	4.56	4.63	51.12	6.21	198.23	3.48 (1.26)[#]	0.6 (1.26)[#]	12.34
T_2, Salicylic acid 100 ppm	10.64	56.34	6.60	6.49	55.88	7.86	222.38	3.33 (1.09)	0.2 (1.09)	12.35
T_3, Salicylic acid 150 ppm	8.36	55.02	5.49	5.27	52.98	7.38	206.47	3.40 (1.63)	1.7 (1.63)	12.37
T_4, Cycocel 1,500 ppm	8.11	52.70	4.86	4.76	50.65	6.49	192.54	4.16 (1.60)	1.6 (1.60)	12.38
T_5, Cycocel 2,000 ppm	8.37	51.14	4.72	4.94	51.01	7.05	206.33	4.03 (1.49)	1.3 (1.49)	12.42
T_6, Cycocel 2,500 ppm	9.43	50.17	5.69	5.09	53.76	7.61	211.56	3.18 (1.38)	1.0 (1.38)	12.48
T_7, Etheral 1,000 ppm	7.58	59.18	5.13	4.45	51.52	7.08	204.23	3.51 (1.67)	1.8 (1.67)	12.11
T_8, Etheral 2,000 ppm	7.60	58.80	5.11	4.92	50.23	6.16	185.68	4.01 (1.80)	2.2 (1.80)	12.10
T_9, Etheral 3,000 ppm	8.12	55.46	4.22	4.18	47.66	5.55	181.42	4.21 (1.88)	2.5 (1.88)	12.03
T_{10}, Mancozeb (2.5g/litre)	8.38	64.69	3.56	4.42	47.15	5.41	179.10	6.62 (2.82)	7.0 (2.82)	12.43
T_{11}, Carbendazim (1g/litre)	7.53	62.48	4.94	3.91	48.21	5.47	180.47	7.80 (3.04)	8.3 (3.04)	12.38
T_{12}, Streptocyclin (500 ppm)	6.23	61.74	3.72	4.39	46.73	4.38	165.11	6.94 (2.78)	6.7 (2.78)	12.29
T_{13}, Control (no application)	6.08	62.44	3.46	3.53	45.44	4.32	154.72	8.48 (3.25)	9.57 (3.25)	12.25
Mean	7.98	57.23	4.77	4.69	50.18	6.23	191.40	2.38	1.87	12.30
SEm±	0.73	1.52	0.48	0.46	1.04	0.42	8.61	0.14	0.14	NS
CD (P=0.05)	2.09	4.36	1.370	1.30	2.98	1.21	24.65	0.30	0.29	NS

Figures in parentheses are square-root transformation

to treatments except TSS content. Leaves are the primary way of plants that interact with the atmosphere and take care of their basic needs. More number of healthy leaves are pre requisite for good yield. Significantly maximum (10.64 cm) number of leaves were recorded with the application of 100 ppm salicylic acid, whereas the minimum (6.08 cm) with the control. Role of salicylic acid in enhancing cell-division activity may be owing increased accumulation of proline and endogenous phyto hormones like IAA, GA_3 and cytokinins and reducing ABA content. Islam *et al*. (2007) revealed that, bio-regulators make a shift in hormonal balance characterized by increasing in endogenous phytohormone in plant. Maximum plant height (64.69 cm) was observed with mancozeb 2.5 g/litre which was statistically at par with carbendazim 1g/litre and streptocyclin 500 ppm, whereas the minimum plant height (50.17 cm) was found with the cycocel 2,500 ppm. The excessive vegetative growth is a problem in *kharif* onion. As a result of more vegetative growth, bulb size remains small and thus yield is reduced. This is due to poor translocation of assimilates from leaves to bulbs as a result of altered source to sink relationship due to application of plant growth-regulators. However, significant reduction in plant height can be seen with the treatment of cycocel and salicylic acid. This may be due to slowing down of cell-division and reduction in cell expansion (Kumar *et al.,* 2017). Maximum values of polar and equatorial diameter were recorded with the spray of salicylic acid 100 ppm, followed by cycocel 2,500 ppm whereas the minimum values for polar and equatorial diameter were observed in the control. The application of growth-regulators significantly improved the bulb weight. Salicylic acid @ 100 ppm exhibited significantly higher value for bulb weight (55.88 g), followed by cycocel 2,500 ppm and salicylic acid 150 ppm, whereas the minimum bulb weight was recorded in thecontrol (45.44 g) which was statistically at par with mancozeb 2.5 g/litre, streptocyclin 500 ppm and carbendazim1 g/litre. It could be noticed that plants treated with salicylic acid (100 ppm) and cycocel (2,500 ppm) resulted in the highest polar and equatorial diameter of bulb as compared to all the other treatments. Thus, spraying onion plant with these growth-regulators resulted in rapid cell-division and elongation leading to bigger bulb formation.

Bulb yield

Different treatments significantly affected bulb yield/plot. Maximum yield per plot as well as per hectare were observed with salicylic acid 100 ppm, which was statistically at par with cycocel 2,500 ppm, salicylic acid 150 ppm, etheral 1,000 ppm and ppm cycocel 2000, while the control treatment showed the minimum bulb yield per plot

and per hectare. Significantly higher yield was observed with the application of SA and CCC as compared to all the other treatments and control. It may be owing to the role of these growth-regulators on enhancing cell-division activity, increasing proline accumulation in plant and increasing the endogenous phytohormones, i.e. growth-promoting hormones. Salicylic acid (SA) altered the auxin, cytokinin and ABA balances in crop plants and increased the growth and yield under both normal and stress conditions. Similar results were observed by Anbukkarasi *et al*. (2014) and Sathiyamurthy *et al*. (2017). In addition, SA also protect the plants from heat stress by increasing N assimilation and allocation of N to Rubisco protein photosynthetic (NUE). Photosynthetic NUE is an important tool to improve the inherent variation in photosynthetic capacity, which increases if more leaf N is allocated to Rubisco. The increased N assimilation in plants receiving SA provides N backbone for chlorophyll and proline synthesis. The SA improves growth parameters and yield at low and moderate concentration. However at higher doses, SA had negative effects on seed germination and growth (Khan *et al.* 2013). Negative effects of SA on seed germination is presumably due to an SA-induced oxidative stress at higher doses. CCC (2,500 ppm) also revealed at par performance with SA (100 ppm) for many traits. This could be owing to increase in number of leaves, bulb diameter, and increasing of endogenous phytohormones, i.e. increasing promotion hormones (IAA, GA_3 and cytokinins) and reducing ABA content in plants.

Bolters and doublers

All the treatments exhibited significant variation for bolters and doublers percentage. Minimum bolting percentage (3.18%) was recorded with the cycocel 2,500 ppm and the maximum in the control (8.48%). Minimum doublers (0.2 %) were observed under treatment T_2 (salicylic acid 100 ppm) and maximum in T_{13} (control). Treatments effect on TSS was found non-significant. Sathiyamurthy *et al*. (2017) and Dwivedi *et al.* (2019) also reported positive effects of plant growth-regulators on onion.

Storage losses

The data pertaining to different storage losses like weight loss, loss in bulb diameter, black mould per cent, rotting and sprouting losses are presented in Fig. 1. Significant variation was recorded for these traits due to different treatments.

Minimum (7.10%, 12.21% and 27.48%) and maximum (18.14%, 27.12% and 50.33%) weight losses were observed under the treatments T_2 (salicylic acid 100 ppm) and $T_{13,}$ (control) 30, 60 and 90 days of storage respectively. After 3 months of storage life, per cent loss in bulb diameter was maximum (2.24, 5.39 and 8.24%) in the control treatment and application of 100 ppm salicylic acid showed significantly minimum (1.12, 2.12 and 3.13%) loss in bulb diameter at 30, 60 and 90 days of storage, respectively. The least percentage of rotted (1.12, 2.01 and 4.11%) and sprouted bulbs (11.76, 24.25 and 48.41%) after 30, 60 and 90 days of storage were noticed in with the treatment of 100 ppm salicylic acid, followed by treatment application of cycocel 2,500 ppm which indicate the efficacy of these growth-regulators in checking storage loss. This may be owing to the application of these chemicals at desired doses which was found to be more effective in decreasing the per cent rotting and sprouting rather using them at some other concentrations. Exogenous application of SA at non-toxic concentration to susceptible fruits and vegetables could enhance resistance to pathogens and control post-harvest decay. It also exhibits direct antifungal effects against pathogens (Loake and Grant, 2007). Plants protect themselves against the pathogen attacks by activating some kinds of defense mechanisms such as local acquired resistance (LAR) and systemic acquired resistance (SAR). Even the growth-retardant cycocel is also known to decrease per cent rotting in onion, when sprayed at the rate of 2,500 ppm at 75 and 90 days after transplanting. The highest rotting (8.14%) and sprouting losses (85.78%) after 90 days of storage were found under the control treatment which may be due to the fact that control plots did not receive any growth-regulators and fungicides application before the harvesting and as a result they sprouted quickly and more attacked by bacteria and fungi during storage as compared to the other treatments. In the present investigation, the incidence of black mould increased with the increase in storage period. The least incidence of black mould (2.36%) after 90 days of storage was noticed with the treatment of salicylic acid (100 ppm) and it was at par with salicylic acid (50 ppm), salicylic acid (150 ppm) and cycocel (2,500

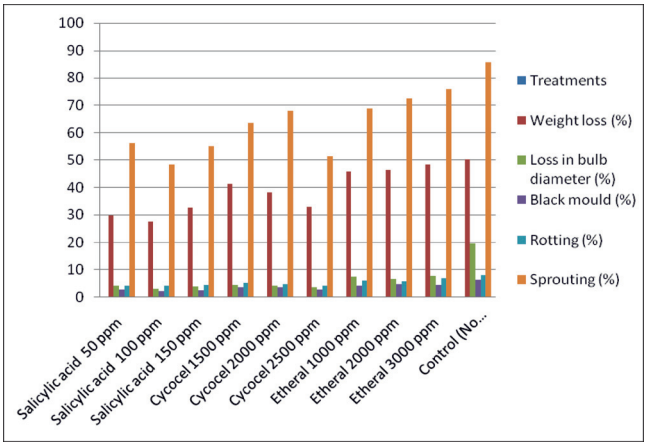

Fig. 1. Effect of different concentration of growth-regulators on storage losses in rainy season onion

ppm). Significantly higher incidence of black mould (6.41%) was observed in the control treatment. The SA and CCC were found effective in checking black mould. The SA induced SAR which might have helped in minimizing the disease incidence. Salicylic acid (SA) plays important role in activation of plant defense systems against pathogen attacks. Cycocel a growth-retardant substance, reduces the respiration rate of bulbs, which in turn reduces the loss of moisture from the bulbs thus creating unfavorable environment for growth of pathogen thus result in reduced incidence of black mould.

Salicylic acid at the concentration 100 ppm performed best over all the other treatments with significantly higher bulb yield and other growth parameters like number of leaves, polar and equatorial diameter, bulb weight. This treatment was also found best under 3 months storage period with significantly lesser post-harvest losses, i.e. minimum rotting, sprouting and black mould incidence. This was closely followed by treatment of cycocel at 2,500 ppm concentration. This indicates the efficacy of these growth-regulators for increased yield and enhanced storage life of *kharif* onion.

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