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Influence of plant growth retardants on growth, seed yield and quality in onion (*Allium cepa*) cv. Pusa Riddhi

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ABSTRACT

A field experiment was conducted at New Delhi during *rabi* 2013-14 and 2014-15 to evaluate the effect of growth retardants on seed scape height, seed yield and quality attributes in onion (*Allium cepa* L.) cv. Pusa Riddhi.The experiment consisted of 15 treatments in combinations of three growth retardants, viz. paclobutrazol, ethephon and triadimefon. The results revealed that among different growth retardants, 100 ppm paclobutrazol significantly reduced the seed scape height (69.9 cm) and increased the seed scape diameter (3.71 cm). The paclobutrazol application also significantly improved the umbel diameter, umbellates/umbel, productive umbellates/umbel, seed setting (%), 1 000 seed weight and seed yield/umbel but it reduced the leaves/plant and seed scapes/plant. The triadimefon treatment significantly reduced the disease severity and disease incidence which affects the seed yield and quality. Seed quality attributes were not much influenced by growth retardant applications but higher seed vigour index-I (952.14) and II (186.13) were recorded under triadimefon and paclobutrazol treatments respectively. Paclobutrazol application also influenced the total leaf chlorophyll content and seed antioxidant enzymes, viz. SOD, catalase and glutathione reductase over the control treatment.

Key words: Antioxidants, Growth retardants, Onion**,** Pusa Riddhi, Seed scape, Umbellates

In India onion (*Allium cepa* L.) seed production is largely concentrated in Maharashtra, Karnataka, Gujarat and Madhya Pradesh and there is a need of development of new alternative areas for onion seed production to meet the market demand of quality seed. North India is one of the potential onion growing regions but onion seed production in this region is greatly affected by biotic and abiotic factors resulting in lower seed yield and quality. Quality seed production of onion depends on genotype, locality, season and method of seed production (Brewster 1994). Despite many attempts in the recent past, to enhance the yield and quality of onion seed (Bhonde *et al*. 1996) no definite and profitable technology has yet been developed which can be recommended to the farmers for growing onion seed at commercial scale under north Indian conditions where climatic conditions change suddenly during flowering and maturity of seed crop.

In onion, seed umbel is born on terminal part of hollow seed scape and this seed scape length in most of the cultivars is very high. The high length of hollow seed scape and high wind velocity due to western disturbance during the flowering and maturation of crop increase the chance of seed scape lodging in north Indian conditions. Because of seed scape lodging it prevents the mechanical harvesting and also decreases the seed yield and quality. Plant growth retardants have been used to modify the growth and development of many vegetable crops (Berova *et al*. 2002). Plant growth retardant like paclobutrazol was used to reduce the onion seed scape height, but along with reducing scape height it also significantly reduced the seed yield parameters (Ashrafuzzaman *et al*. 2009). In onion, suitability of plant growth retardants for reducing the seed scape height as well as their optimum requirement to give better results in terms of quantity and quality of onion seed is yet to be worked out.

MATERIALS AND METHODS

A field experiment was carried out for two consecutive years during *rabi* 2013-14 and 2014-15 at the Seed Production Unit farm of Indian Agricultural Research Institute, New Delhi. Medium size (60-80 gm) bulbs of onion cv. Pusa Riddhi were raised during previous season of experiments were used as planting materials in the subsequent year experiments. The three growth retardants, viz. paclobutrazol (Celstar), ethephon (Ethrel) and triadimefon (Bayleton) were used in the experiment which contain 23, 52 and 25% active ingredient compounds,

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Table 1 Plant growth retardants combinations

	Plant growth retardant treatments
T_1	Soaking of bulbs in 80 ppm paclobutrazol solution
T_2	Foliar spray of paclobutrazol @ 80 ppm
T_3	Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4	Soaking of bulbs in 100 ppm paclobutrazol solution
T_5	Foliar spray of paclobutrazol @ 100 ppm
T_6	Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7	Soaking of bulbs in 400 ppm ethephon solution
T_8	Foliar spray of ethephon @ 400 ppm
T_9	Soaking of bulbs in 500 ppm ethephon solution
T_{10}	Foliar spray of ethephon @ 500 ppm
T_{11}	Soaking of bulbs in 200 ppm triadimefon solution
T_{12}	Foliar spray of triadimefon @ 200 ppm
T_{13}	Soaking of bulbs in 400 ppm triadimefon solution
T_{14}	Foliar spray of triadimefon @ 400 ppm
T_{15}	Control (Water spray)

respectively. These chemicals were dissolved in water as per the treatment concentration and bulbs were soaked in solution for overnight (Table 1). Treated bulbs were dried in shade and then planted in 3m×3m plots with 60×30 cm spacing. The foliar spray of growth retardants were given according to treatment concentration at seed scape emergence stage. All the recommended package of practices was uniformly followed in all treatments. The necessary plant protection measures were adopted by using regent (Fipronil) @10 kg/acre and jump (Fipronil) @40 g/ha to control thrips and other insects while nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) @ 100g/acre was applied at 25 DAP and at bolting stage to avoid the fungal diseases (stemphylium blight and purple blotch). The observations on growth attributes were recorded from randomly selected 10 plants and seed quality attributes were evaluated as per the guidelines of ISTA (2012) while, seed vigour-I and II were calculated as suggested by Abdul-Baki and Anderson (1973). Total leaf chlorophyll was measured as method suggested by Hiscox and Israelstam (1979) by using dimethyl sulfoxide (DMSO). The disease severity on seed scape was scored based on 0-4 scales (Behera *et al*. 2013) as follows; 0= No disease symptoms, 1=1-25% seed scape area infected, 2=25-50% seed scape area infected, 3=50-75% seed scape area infected, 4=57-100% seed scape area infected and percentage disease index (PDI) was calculated by the formula given by Wheeler (1969).

$$PDI = \frac{\text{Total sum of numerical ratings}}{\text{Number of observations}} \times \frac{100}{\text{Maximum disease rating}}$$

The superoxide dismutase activity was measured by the procedure given by Dhindsa *et al*. (1981) while, catalase activity was measured by the procedure given by Aebi (1984) through measuring the disappearance of H_2O_2 (ε=39.4 m/M/cm). Peroxidase activity (POX) was measured by the procedure given by Rao *et al.* (1996) through monitoring the formation of tetraguaiacol (ε=26.6 m/M/cm) from guaiacol and glutathione reductase was estimated based on the formation of red coloured complex by reduced glutathione with 5, 5-dithiobis-2-nitrobenzoic acid (DTNB) (Smith *et al*. 1988).The data on quantity observations recorded were subjected to statistical analysis by adopting split plot design using SAS 9.3 and the percentage data were transformed into arcsine value for analysis.

RESULTS AND DISCUSSION

Plant growth retardants significantly influenced growth attributes in onion (Table 2). The number of leaves/plant were significantly reduced with paclobutrazol application and treatments, viz. T_1, T_3, T_4 and T_6 registered lower number of leaves/plant (26.28, 24.93, 25.65 and 24.58, respectively). The reduction in number of leaves in paclobutrazol might be due to the inhibition of GA synthesis pathway. The findings are in agreement with the reports of Globerson *et al.* (1989) and Ashrafuzzaman *et al*. (2009) in onion. Higher number of days (71.50) for emergence of seed scape was reported in paclobutrazol 100 ppm treatments than control (53.40) (Table 2). The significant delay in the seed scape emergence with the application of paclobutrazol (soaking + foliar spray) could be due to the inhibitory action of the paclobutrazol on biosynthesis of endogenous hormones specially GA. The growth retardant treatments particularly paclobutrazol either through foliar spray or soaking of bulb significantly decreased the seed scape height (Table 2). The significantly low seed scape height was recorded in T6 (69.9 cm) followed by T3 (77.35 cm) and T4 (80.93 cm) than control (T15) (103.25 cm). The significant reduction in seed scape height by use of paclobutrazol and comparative reduction by ethephon and triadimefon attributed to the fact that these retardants act on isopropanoid pathway and block the production of GAs which is required for scape expansion. The similar results were also reported by Mansuroglu *et al.* (2009) and Currey and Lopez (2010). The higher seed scape diameter was recorded in T4 (3.71 cm) followed by T6 (3.68 cm) and T1 (3.67 cm). The growth retardants increase the scape diameter by blocking of GAs synthesis which reduced the cell elongation but there was continuous cell division still occurs leads to formation of additional palisade and spongy cells layers (Burrows *et al*. 1992, Jaleel *et al*. 2007) resulting into increase in thickness of stem (Fleture *et al.* 2000). The growth retardants application changes the number of seed scapes/plant and higher number of seed scapes/plant was observed in T_8 (11.58) followed by T_5 (10.95) and T_9 (10.70). However, paclobutrazol application significantly reduced the number of seed scapes per plant and lower number of seed scapes/plant was recorded in T4 (5.83) followed by T1 (6.70) and T6 (6.80). Application of growth retardants did not affect the disease incidence but numerically, low disease incidence was recorded in triadimefon treatments. Whereas, disease severity (PDI) was significantly affected by growth retardants application (Table 2) and lower PDI

Table 2 Effect of plant growth retardants on growth and disease incidence in onion cv. Pusa Riddhi (Pooled data over two years)

Treatment	Number of leaves/ plant	Seed scapes emergence (Days)	Seed scape height (cm)	Seed scape diameter (cm)	Seed scapes/ plant	Productive seed scapes/ plant	Seed scape lodging (%)	Disease infected plants (%)	PDI
T_{1}	26.28^{b}	70.25^{a}	81.33^{def}	3.67^{a}	6.70^{c}	3.42^{b}	(44.45) 49.08^{ab}	(26.17) 19.5	5.62^{b}
T_{2}	33.33^{a}	54.75^{b}	86.95^{bcde}	3.41^{a}	10.18^{a}	6.92^{a}	(34.35) 31.94^{defg}	(24.66) 17.5	5.54^{b}
T_{3}	24.93^{b}	68.50^{a}	77.35^{ef}	3.66^{a}	7.30^{bc}	3.25^{b}	(48.36) 54.99^{a}	(25.41) 18.5	5.50^{b}
T_{4}	25.65^{b}	69.00^{a}	80.93^{def}	3.71^{a}	5.83^{c}	3.27^{b}	(41.13) 43.48^{abcd}	(24.97) 18.0	5.25^{bc}
T_{5}	34.55^{a}	55.25^{b}	86 .4^{bcde}	3.33^{a}	10.95^{a}	6.88^{a}	(37.52) 37.12^{bcde}	(25.01) 18.0	5.75^{b}
T_{6}	24.58^{b}	71.50^{a}	69.9^{f}	3.68^{a}	6.80^{c}	3.42^{b}	(45.03) 50.07^{abc}	(25.79) 19.0	5.75^{b}
T_{7}	35.28^{a}	54.00^{b}	99.35^{ab}	2.49^{b}	10.48^{a}	7.08^{a}	(34.58) 32.39^{de}	(26.15) 19.5	7.37^{a}
T_{8}	35.78^{a}	53.75^{b}	97.73^{abc}	2.69^{b}	11.58^{a}	7.37^{a}	(36.79) 36.07^{bcde}	(26.49) 20.0	6.79^{a}
T_{9}	34.40^{a}	54.25^{b}	100^{ab}	2.57^{b}	10.70^{a}	7.20^{a}	(34.84)32.67^{cde}	(26.13) 19.5	6.37^{b}
T_{10}	33.68^{a}	55.75^{b}	96.55^{abc}	2.50^{b}	9.53^{ab}	7.05^{a}	(33.52) 32.63^{de}	(26.47) 20.0	6.58^{a}
T_{11}	34.45^{a}	54.25^{b}	94.7^{abcd}	2.39^{b}	9.45^{ab}	7.12^{a}	(29.7) 24.6^{e}	(24.70) 17.5	5.16^{bc}
T_{12}	34.90^{a}	55.25^{b}	94.05^{abcd}	2.55^{b}	10.55^{a}	7.27^{a}	(28.58) 23.34^{e}	(23.89) 16.5	5.33^{bc}
T_{13}	34.30^{a}	53.50^{b}	94.25^{abcd}	2.51^{b}	10.03^{a}	7.30^{a}	(29.48) 26.79^{e}	(23.12) 15.5	4.50^{bc}
T_{14}	33.63^{a}	54.75^{b}	96.58^{abc}	2.65^{b}	10.40^{a}	7.00^{a}	(34.43) 25.89^{e}	(24.23) 17.0	5.16^{bc}
T_{15}	36.13^{a}	53.50^{b}	103.25^{a}	2.36^{b}	10.53^{a}	8.02^{a}	(33.65) 30.87^{de}	(28.23) 22.5	6.75^{a}
Mean	32.12	56.71	90.62	2.95	9.40	6.17	(36.42) 35.46	(25.43) 18.57	5.83
SE(d)	1.35	1.72	7.07	0.14	0.60	0.50	0.70	2.735	0.39
HSD (P=0.05)	5.03	6.38	2.62	0.54	2.25	1.85	2.62	NS	0.85

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant. *Significant effects are shown with group letters, SE(d)-Standard error of difference. ** Values in parenthesis are arcsine value.

was recorded in T_{13} (4.50%) followed by T_{14} (5.16%) and T_{4} (5.25%). The lower PDI could be due to the changes in ergosterol biosynthesis (Fleture 2000) because these compounds inhibit one specific enzyme, C_{14}-demethylase, which is essential for sterol production and sterols, particularly ergosterols are useful for membrane structure and development of fungus cell wall. Therefore, due to these trizoles compound there is abnormal growth and

Table 3 Effect of plant growth retardants on flowering and seed yield attributes in onion cv. Pusa Riddhi (Pooled data over two years)

Treatment	Umbel diameter (cm)	Umbellates/ umbel	Productive umbellates/umbel	Seed setting (%)	1,000 seed weight (gm)	Seed yield/ umbel (g)	Seed yield/ plant (g)	Seed yield/ ha (q)
T_{1}	7.14^{a}	627.0^{a}	424.70^{ab}	(55.37) 67.74^{abc}	3.11^{ab}	3.43^{ab}	6.90^{d}	3.45^{d}
T_{2}	7.02^{a}	552.65^{b}	417.65^{abc}	(60.36) 75.57^{ab}	2.94^{ab}	2.86^{ab}	10.50^{c}	5.25^{c}
T_{3}	7.19^{a}	617.80^{a}	431.75^{a}	(56.69) 69.89^{abc}	3.18^{ab}	3.37^{ab}	6.63^{d}	3.31^{d}
T_{4}	7.20^{a}	630.35^{a}	441.60^{a}	(56.80) 70.06^{abc}	3.08^{ab}	3.39^{ab}	6.93^{d}	3.46^{d}
T_{5}	6.92^{a}	552.55^{b}	418.90^{abc}	(60.52) 75.81^{a}	2.94^{ab}	3.03^{ab}	10.63^{c}	5.31^{c}
T_{6}	7.31^{a}	628.05^{a}	444.80^{a}	(57.28) 70.82^{abc}	3.32^{a}	3.48^{a}	6.18^{d}	3.09^{d}
T_{7}	6.22^{b}	525.10^{b}	371.75^{bcd}	(57.30) 70.8^{abc}	2.88^{ab}	2.87^{ab}	10.93^{bc}	5.46^{bc}
T_{8}	6.25^{b}	534.70^{b}	362.25^{cd}	(55.50) 67.89^{abc}	2.78^{b}	2.79^{b}	10.68^{c}	5.34^{c}
T_{9}	6.23^{b}	531.20^{b}	341.85^{d}	(53.63) 64.64^{c}	2.82^{ab}	3.01^{ab}	10.68^{c}	5.34^{c}
T_{10}	6.24^{b}	534.65^{b}	355.30^{d}	(54.57) 66.39^{bc}	3.02^{ab}	3.07^{ab}	10.90^{bc}	5.45^{bc}
T_{11}	6.36^{b}	516.70^{b}	364.50^{cd}	(54.69) 66.55^{bc}	2.96^{ab}	2.92^{ab}	12.05^{abc}	6.03^{abc}
T_{12}	6.23^{b}	536.55^{b}	344.40^{d}	(53.22) 64.16^{c}	2.84^{ab}	2.87^{ab}	11.75^{abc}	5.88^{abc}
T_{13}	6.35^{b}	525.90^{b}	355.15^{d}	(55.40) 67.66^{abc}	2.84^{ab}	2.84^{ab}	12.40^{ab}	6.20^{ab}
T_{14}	6.37^{b}	526.40^{b}	342.65^{d}	(53.76) 65.09^{c}	2.89^{ab}	2.91^{ab}	12.67^{a}	6.34^{a}
T_{15}	6.12^{b}	514.25^{b}	343.0^{d}	(57.40) 70.92^{abc}	2.72^{b}	2.79^{b}	11.72^{abc}	5.86^{abc}
Mean	6.61	556.92	384.02	(56.18) 68.94	2.96	3.04	10.10	5.05
SE(d)	0.10	10.86	15.97	0.70	0.14	0.17	0.46	0.23
HSD (P=0.05)	0.39	40.28	59.20	2.62	0.54	0.65	1.72	0.86

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant. *Significant effects are shown with group letters, SE(d)-Standard error of difference. ** Values in parenthesis are arcsine value.

eventually death of fungus as reported by Fletcher *et al.* (1986) and Tadao *et al*. (2003).

Significantly higher umbel diameter (7.31cm) and number of productive umbellates/umbel (444.80) were recorded in T_6 (soaking + spray of 100 ppm paclobutrazol) as compared to other treatments. It could be attributed to higher production of cytokinin due to the application of trizole compounds (Fleture *et al.* 2000, Kamountsis *et al.* 1999) which enhanced the reproductive growth of plants as reported by Isabel *et al.* (2011) in Arabidopsis and Gomathinayagam *et al*. (2007) in cassava.The foliar spray of paclobutrazol @ 100 ppm (T_5) showed significantly higher seed setting (75.81%) followed by foliar spray of 80 ppm paclobutrazol (Table 3). The higher seed setting per cent in T_5 and T_2 is comparative performance between the number of umbellates/umbel and productive umbellates/ umbel resulted into higher seed setting. The significantly higher 1 000 seed weight was recorded in paclobutrazol (T_1) (3.32g) followed by T_3 (3.18g) and T_6 (3.11g). The superiority of 1,000 seed weight in T1 (soaking of bulbs in 80 ppm paclobutrazol) attributed to higher accumulation of food reserve due to lower number of seed scapes/plant and is conformity with Ashrafuzzaman *et al*. (2009).

Difference was observed for seed yield/umbel with growth retardants application (Table 3) and significantly higher seed yield/umbel was observed in T_6 (3.48g) followed by T_1 (3.43g) and T_4 (3.39g). Whereas, significantly higher seed yield/plant was recorded in foliar spray of 400 ppm triadimefon (T_{14}) (12.67g) followed by T_{13} (12.40g) and T_{11} (12.05g). The significant higher seed yield/ha was recorded in foliar spray of 400 ppm triadimefon (T_{14}) (6.34q) followed by T_{13} (6.20q) and T_{11} (6.03q) which could be due to less disease incidence and severity, higher productive seed scapes/plant and less seed scape lodging that had resulted into higher seed yield. The results are in conformity with Ashrafuzzaman *et al*. (2009).

Growth retardants had non-significant effect on seed germination (Table 4) however, higher seedling dry weight was recorded in paclobutrazol treatment (T_1 and T_2) (each 2.07 mg) which was at par with other treatments except T_6 (1.44 mg). The superior seedling dry weight could be due to the better food reserve in seed. Seed vigour index-I showed significant difference due to use of growth retardants (Table 4). The significant higher vigour index-I was recorded in T_{15} (952.14) followed by T_{14} (950.36) which could be due to higher seedling length.

The application of growth retardants had influence on biochemical parameters, viz. leaf chlorophyll content and antioxidant enzymes content of seed. Higher total chlorophyll content was observed in paclobutrazol treatments than control and other treatments. The higher total chlorophyll content in paclobutrazol treatments could be due to that trizole compounds induced the cytokinin production which enhances the chloroplast size and chlorophyll content. The inhibition of GAs pathway which controls the cell size but there is continuous synthesis of chlorophyll resulting into densely packing of chlorophyll makes the leaf greener than control. The results are corroborated with Pinhero and Fletcher (1994) in maize seedlings and Nouriyani *et al*. (2012) in wheat seedling.

Table 4 Effect of plant growth retardants on seed quality attributes in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Germination (%)	Seedling lengh (cm)	Seedling dry weight (mg)	EC (µmhos/ cm/g)	Seed vigour index-II
T_1	89.91 (71.46)	10.20	2.07^{a}	2.46	186.13^{a}
T_2	88.75 (70.50)	10.25	2.07^{a}	2.34	183.59^{a}
T_3	90.33 (71.81)	9.28	1.56^{bc}	2.59	141.03^{bc}
T_4	89.83 (71.46)	10.11	1.81^{ab}	2.61	162.49^{ab}
T_5	88.74 (70.41)	10.63	1.85^{ab}	2.48	164.58^{ab}
T_6	89.75 (71.43)	8.48	1.44^{c}	2.45	129.12^{c}
T_7	89.33 (71.20)	10.33	1.90^{ab}	2.26	169.76^{ab}
T_8	91.08 (74.35)	10.41	1.97^{a}	2.57	178.40^{a}
T_9	88.16 (71.35)	10.29	1.94^{a}	2.36	171.31^{ab}
T_{10}	88.91 (70.56)	10.34	1.98^{a}	2.57	175.85^{a}
T_{11}	88.75 (70.62)	10.40	1.86^{ab}	2.30	165.26^{ab}
T_{12}	88.41 (70.53)	10.38	2.0^{a}	2.51	176.44^{a}
T_{13}	88.33 (70.03)	10.67	1.88^{ab}	2.48	166.27^{ab}
T_{14}	88.16 (70.86)	10.78	1.98^{a}	2.30	174.25^{ab}
T_{15}	87.99 (71.74)	10.82	2.03^{a}	2.30	178.67^{a}
Mean	89.10 (71.23)	31.98	1.89	2.44	168.21
SE(d)	1.92	0.70	0.09	0.16	8.99
HSD (*P*=0.05)	NS	NS	0.36	NS	33.34

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant. *Significant effects are shown with group letters, SE(d)- Standard error of difference. ** Values in parenthesis are arcsine value.

The antioxidants, viz. superoxide dismutase (SOD), catalase and glutathione reductase activity were highly influenced by growth retardants particularly paclobutrazol application. The higher activity of antioxidants in growth retardants treatment could be due to stress condition induced by trizoles compounds which promoted the activity of these enzymes. These triazole compounds may protect membrane components from oxidative damage and lipid peroxidation during abiotic stress conditions by increasing the defense mechanisms of the local tissues against free radicals (Fletcher and Hofstra 1990, Fleture *et al.* 2000). The similar results were also reported by different workers (Nair *et al*. 2012, Sivakumar and Panneerselvam 2011).

From the study it was concluded that paclobutrazol significantly reduced the scape height and increase the scape diameter which resulted into lower scape lodging during harvesting time. Paclobutrazol application also increases seed yield and seed antioxidants properties in onion.

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