International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 295-298
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Received: 07-09-2018
Accepted: 09-10-2018

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Influence of field application of salicylic acid, azoxystrobin and cycocel on storage behavior of onion (*Allium cepa* L.) var. Arka Kalyan

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Abstract
Onion is an important commercial vegetable crop across the world, demands good storage due to its seasonality. However huge post harvest loss of onion was noticed during storage in the form of sprouting, rotting and physiological loss in weight resulting in least quantum of marketable bulbs. To overcome this bottleneck a field study was carried out at College of Horticulture, Bagalkot to evaluate the influence of pre harvest application of salicylic acid, azoxystrobin and cycocel on storage behavior of onion cv. Arka Kalyan. The experiment was laid on Randomized Complete Block Design, with 12 treatments and 3 replication. The chemicals *i.e.,* salicylic acid, azoxystrobin and cycocel were applied in the field and their effect on various physicochemical parameters were studied at monthly interval during prolonged storage of 4 months. The combined application of chemicals resulted in least per cent rotting, black mould incidence and improved quantum of marketable bulb and total phenols.

Keywords: Onion, salicylic acid, cycocel (CCC), azoxystrobin and days after transplanting (DAT)

Introduction
Onion (*Allium cepa* L.) is extremely important vegetable crop valued for internal consumption and is the highest foreign exchange earner among the vegetables and fruits. It 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 per cent storage losses depending upon genotype and storage conditions (Shivakumar and Chandrashekar, 2014) [10]. It is stored for long period for use in off season as well as for export but the present storage methods in India is quite inadequate and most of them are traditional and unscientific.

The application of plant growth regulator and fungicides could be employed as pre-harvest foliar spray 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. On the other hand storage of onion in improved storage structures demands high cost which is not affordable by Indian farming community. Based on this concept growth regulator like cycocel (CCC) and salicylic acid and fungicide like azoxystrobin were applied in the field to check their efficacy in storage on various parameters like incidence of black mould, rotting, quantum of marketable bulb and total phenol content.

Material and methods
The experiment was conducted at College of Horticulture, Bagalkot during *kharif* season of 2016-17. Bagalkot is situated in the Northern Dry Zone (Zone-3) between 16° 10' N and 75° 42' E longitude of Karnataka. The altitude of place is 542.00 m above mean sea level. Bagalkot district possess arid and semi-arid region with mean annual rainfall of 517.3 mm and mean temperature of 32.6°C. The experiment was laid out in Randomized Complete Block Design with three replications and twelve treatments. Seedlings from the nursery beds were transplanted to the main field at a spacing of 15 cm x 10 cm. The variety Arka Kalyan released by IIHR was subjected to the study.

Treatment details

T_1	**Control**
T_2	Pre-harvest spray of SA(2 mM) at 60 + 90 DAT
T_3	Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT
T_4	Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT
T_5	Pre-harvest spray of SA (2 mM) and azoxystrobin (0.1%) at 60 + 90 DAT
T_6	Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) followed by foliar spray of azoxystrobin (0.1%) at 60 + 90 DAT
T_7	Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_8	Pre-harvest spray of SA (2 mM) at 60 + 90 DAT and foliar spray of cycocel 2500 ppm at 90 DAT
T_9	Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT and foliar spray CCC (2500 ppm) at 90 DAT
T_{10}	Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray of cycocel (2500 ppm) at 90 DAT
T_{11}	Pre-harvest spray of SA (2mM) and azoxystrobin (0.1%) at 60 + 90 DAT followed by CCC (2500 ppm) foliar spray at 90 DAT
T_{12}	Seedling dip in SA 2 mM + Pre-harvest spray of SA (2 mM) and azoxystrobin (0.1%) at 60 + 90 DAT followed by foliar spray of CCC (2500 ppm) at 90 DAT

The bulbs were harvested at 50 per cent neck fall around 120 days after transplanting (DAT) harvested bulbs were well cured and packed in gunny bags of size 45 cm × 60 cm then subjected to prolonged storage of 4 months. During this period various parameters such as incidence of black mould, rotting per centage, marketable bulbs were estimated in accordance with Kukanoor, L., 2005, [8] and phenols were analysed according to Sadasivam and Manickam, 2005 [9].

Results and discussion

Rotting per cent

The per cent rotting losses as influenced by the field application of SA, azoxystrobin and CCC during the storage period of 120 days were significantly influenced among them(table 1). The least rotting was noticed in the treatment T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (1.87%), T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (2.07%), T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (2.12%) and T_{10} (Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (2.54 %). Which may be due to the combined application of chemicals, was found to be more effective in decreasing the per cent rotting rather using them alone. Which indicate the efficacy of chemicals in checking rotting. The exogenous application of SA at nontoxic concentration to susceptible fruits and vegetables could enhance resistance to pathogens and control post-harvest decay (Asghari *et al*., 2009) [4]. It also exhibits direct antifungal effects against pathogens. 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) (Vlot *et al*., 2009) [12]. The fungicide azoxystrobin is one among the strobilurin class of systemic fungicides. It is a broad spectrum fungicide with protectant, curative, eradicant and systemic properties. It travels through leaf surface to leaf tip and growing edges (Arreaza and Hernandez, 2001) [3]. Even the growth retardant cycocel is also known to decrease per cent rotting in onion, when sprayed @ 2500 ppm on 75 and 90 days after transplanting (Anon, 2004) [2].

Incidence of black mould

In the present investigation, the incidence of black mould increased with prolonged storage. The least incidence of black mould was noticed in bulbs with the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (1.63 %) followed by T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (1.74%), T_{10} (Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray cycocel 2500 ppm 90 DAT) (2.01%) and T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (2.05%). This might be due to fungicide azoxystrobin its fungicidal activity which inhibited the mitochondrial respiration of higher fungi (Becker *et al*., 1981) [7]. Alphanso trees sprayed with azoxystrobin @ 2 ml/L suppressed the development of anthracnose (Sundaravadana *et al*., 2006) [11] similar results obtained by Xuequn *et al.* (2012) [13] in mango. In the present investigation combined application of azoxystrobin along with SA and CCC proved best in reduction of black mould incidence. The SA induce SAR which might have helped azoxystrobin in minimizing the disease incidence and CCC 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.

Marketable bulbs

Availability of maximum quantity of healthy and sound bulbs at the end of storage period is of paramount importance for better sale and to get good returns. The quantum availability of the marketable bulbs decreased with prolonged storage of 4 months (Table 3). In the present study maximum per cent marketable bulbs at the end of storage period was obtained in bulbs which are imposed with SA @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm at 90 DAT (T_{11}) (85.54%) at the end of 120 DAS followed by SA@ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT (T_5) (83.52%), Seedling dip in SA@ 2 mM, SA@ 2 mM at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT (T_9) (82.91%), Seedling dip in SA @ 2 mM, SA and SA @ 2 mM, azoxystrobin @ 0.1% at 60 + 90 DAT (T_6) (82.36%) and Seedling dip SA @ 2 mM SA @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT and CCC 2500 ppm foliar spray 90 DAT (T_{12}) (82.32%), This may be attributed to minimum physiological loss in weight (%) (Results are not shown), per cent sprouting (results are not shown) and per cent rotting in these treatments. Similar results were reported by with Kukanoor, L., 2005 [8].

Total phenol content

In the present investigation, with the advancement in storage period, phenols content decreased gradually in all the treatments (Table 4). However, relatively less decrease was observed in bulbs which were treated with seedling dip SA @

2 mM, SA @ 2 mM, azoxystrobin @ 0.1% at 60 + 90 DAT (T_6) (13.73 mg/100g) and bulbs treated with SA @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT (13.54 mg/100g). Which may be due to combined application SA and azoxystrobin resulted in achieving relatively less decrease in phenolic content. This might be due to reduced activity of poly phenol oxidase (PPO) and higher activity of PAL enzymes. PPO is responsible for oxidation of phenolic compounds to quinones and finally to brown polymers (Barman and Asrey, 2014) [6]. SA as a plant harmone regulates the growth and ripening process of fruits as a signaling molecule SA activate the antioxidant mechanism in the plants thus maintained increased level of phenolic compounds (Ali *et al*. 2014) [5]. In addition, the fungicide azoxystrobin is known to increase the activity of many enzymes. Similar results were obtained by Anand *et al*. (2007) [1] where in they observed azoxystrobin increased the defence related enzymes peroxidase, phenyal alanine ammonia lyase and chitinase, defence inducing chemicals and phenolic compounds in cucumber plants.

Table 1: Effect of field application of salicylic acid, azoxystrobin and cycocel on rotting (%) of onion cv. Arka Kalyan

Treatments	Rotting (%)				Mean
	Storage (Days)				
	30	60	90	120	
T_1	2.58^{a}	4.79^{a}	8.30^{a}	12.69^{a}	7.09
T_2	1.41^{bc}	2.84^{cd}	4.11^{c}	5.12^{cd}	3.37
T_3	1.58^{b}	3.31^{bc}	4.04^{c}	5.32^{c}	3.56
T_4	1.14^{cde}	2.16^{ef}	3.01^{e}	4.04^{f}	2.59
T_5	0.72^{e}	1.39^{h}	2.33^{f}	3.05^{g}	1.87
T_6	1.48^{bc}	2.52^{de}	3.96^{c}	5.41^{c}	3.34
T_7	1.32^{bcd}	2.76^{cd}	3.82^{cd}	4.32^{ef}	3.06
T_8	0.80^{e}	1.78^{fgh}	2.51^{f}	3.40^{g}	2.12
T_9	1.25^{bcd}	2.45^{de}	3.47^{d}	4.73^{de}	2.98
T_{10}	1.08^{cde}	2.00^{efg}	3.08^{e}	3.99^{f}	2.54
T_{11}	0.96^{de}	1.51^{gh}	2.41^{f}	3.39^{g}	2.07
T_{12}	1.64^{b}	3.62^{b}	5.15^{b}	7.03^{b}	4.36
Mean	1.33	2.60	3.85	5.21	3.25
S. Em±	0.14	0.19	0.12	0.17	0.15
CD@5%	0.44	0.57	0.38	0.53	0.63

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

Table 2: Effect of field application of salicylic acid, azoxystrobin and cycocel on black mould (%) of onion bulbs (cv.Arka Kalyan) stored under ambient condition

Treatments	Black mould (%)				Mean
	Storage (Days)				
	30	60	90	120	
T_1	1.25^{a}	3.87^{a}	4.93^{a}	6.67^{a}	4.18
T_2	0.89^{abc}	2.82^{c}	3.70^{cd}	4.73^{d}	3.03
T_3	0.92^{abc}	1.78^{e}	3.87^{cd}	4.93^{cd}	2.87
T_4	0.83^{bcd}	1.40^{fg}	2.47^{ef}	3.52^{e}	2.05
T_5	0.57^{bcd}	1.83^{e}	2.73^{e}	3.50^{e}	2.16
T_6	0.52^{d}	2.15^{d}	3.47^{d}	4.80^{cd}	2.73
T_7	0.94^{ab}	3.27^{b}	4.53^{ab}	5.57^{b}	3.58
T_8	0.73^{bcd}	3.12^{bc}	4.60^{ab}	5.33^{bc}	3.45
T_9	0.72^{bcd}	3.00^{bc}	4.13^{bc}	5.10^{bcd}	3.24
T_{10}	0.65^{bcd}	1.71^{ef}	2.43^{ef}	3.27^{ef}	2.01
T_{11}	0.55^{cd}	1.27^{h}	2.17^{f}	3.17^{ef}	1.74
T_{12}	0.50^{d}	1.07^{gh}	2.00^{f}	2.77^{f}	1.63
Mean	0.75	2.27	3.42	4.45	2.72
S. Em±	0.12	0.10	0.18	0.19	0.15
CD@5%	0.37	0.31	0.53	0.56	0.44

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

Table 3: Effect of field application of salicylic acid, azoxystrobin and cycocel on marketable bulb (%) of onion bulbs (cv. Arka Kalyan) stored under ambient condition

Treatments	Marketable bulb (%)				Mean
	Storage (Days)				
	30	60	90	120	
T_1	90.00^{h}	74.27^{e}	63.65^{i}	53.51^{h}	70.36
T_2	92.34^{cde}	81.95^{cd}	73.59^{h}	70.55^{e}	79.61
T_3	92.13^{de}	82.62^{cd}	74.85^{g}	70.79^{e}	80.10
T_4	92.38^{cde}	82.60^{cd}	76.46^{f}	70.54^{e}	80.39
T_5	94.49^{a}	83.64^{bc}	81.58^{bc}	74.36^{b}	83.52
T_6	93.19^{bc}	84.67^{ab}	79.46^{d}	72.12^{cd}	82.36
T_7	91.19^{fg}	81.33^{d}	77.93^{e}	65.40^{g}	78.96
T_8	92.00	84.75^{ab}	79.51^{d}	67.69^{f}	80.97

T_9	93.26 [b]	84.90[ab]	82.54[b]	70.93[de]	82.91
T_{10}	90.72	81.54[d]	78.07[e]	68.57[f]	79.73
T_{11}	94.32[a]	85.73[a]	84.41[a]	77.04[a]	85.54
T_{12}	93.00[bcd]	83.14[bcd]	80.54[cd]	72.61[c]	82.32
Mean	92.42	82.59	77.72	69.51	80.56
S. Em±	0.30	0.65	0.38	0.41	0.44
CD@5%	0.88	1.92	1.14	1.21	1.29

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

Table 4: Effect of on field application of salicylic acid, azoxystrobin and cycocel on total phenol (mg/100g) of onion bulbs (cv. Arka Kalyan) stored under ambient condition.

Treatments	Total phenol (mg/100g)					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	11.67[i]	10.80[f]	10.33[g]	9.37[f]	8.27[e]	10.09
T_2	13.20[ef]	12.67[bc]	11.60[ef]	10.63[de]	9.70[cd]	11.56
T_3	13.47[cde]	12.83[bc]	11.82[cde]	10.80[d]	9.83[c]	11.75
T_4	13.55[cd]	12.90[bc]	11.53[f]	10.77[d]	9.77[c]	11.70
T_5	15.60[a]	14.10[a]	13.70[a]	12.67[a]	11.63[a]	13.54
T_6	15.80[a]	14.33[a]	13.77[a]	12.90[a]	11.83[a]	13.73
T_7	12.37[h]	11.53[e]	10.47[g]	9.30[f]	7.87[f]	10.31
T_8	13.13[f]	12.10[d]	11.60[ef]	10.40 [e]	9.43[d]	11.33
T_9	12.80[g]	12.57[c]	11.70[def]	10.77 [e]	9.73[cd]	11.51
T_{10}	13.38[def]	12.80[bc]	12.00[c]	11.13[c]	10.27[b]	11.92
T_{11}	13.73[c]	13.00[b]	12.80[b]	11.57 [b]	10.57[b]	12.33
T_{12}	14.18[b]	12.83[bc]	11.90[cd]	11.37[bc]	10.33[b]	12.12
Mean	13.57	12.71	11.93	10.97	9.94	11.82
S. Em±	0.10	0.12	0.05	0.10	0.11	0.10
CD@5%	0.31	0.38	0.24	0.29	0.32	0.31

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

Conclusion

The present investigation revealed that combined application of a fungicide azoxystrobin @ 0.1%, and growth regulators salicylic acid@ 2 mM and cycocel @ 2500 ppm was found to be effective in reducing the per cent rotting, black mould incidence and improving the total phenols and percent marketable bulbs with prolonged storage of 4 months.

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