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Management of Onion Bulb Rots during Storage using Pre- and Post- Harvest Control Treatments

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Bulb rot diseases such as black mould, basal rot, neck rot and bacterial soft rot attack onion bulbs during storage and causing losses in onion bulb weight. Black mould and bacterial soft rot recorded the highest considerable disease incidence during three and six months of storage at 2014/2015 and 2015/2016 seasons, followed by basal rot, while neck rot recorded the least incidence in this respect. Most of foliar spraying with fungicides as pre-harvest treatment plus biocides as post-harvest treatment significantly decreased these bulb rots. The most effective combinations in reducing incidence of bulb rots were Bio Nagi plus King star, Acrobat Mancozeb, Ridomil gold plus, or Antracol and Bio Arc combined with Acrobat Mancozeb or Antracol, respectively. Reductions (%) in onion bulbs weight during storage periods, resulted from rots infections, were significantly minimized using most of the combination treatments (pre- plus post-harvest) tested.

Keywords: Biocides, fungicides, onion bulb rots, pre- & post- harvest treatment and storage.

Onion (*Allium cepa* L.) is one of the most important commercial vegetable crops in the world including Egypt (Hussein *et al.,* 2014). It is used throughout the year in the form of salad and for cooking with other vegetables, as well as it has several medicinal uses (Gupta *et al.,* 2012). Onion is highly valued as both flavoring agent and storing plant material for about eight to ten months (Kumar *et al.,* 2015 and Samuel and Ifeanyi, 2015). The cultivated area in Egypt was 196968 fed., in 2014/2015 season, produced 2,888,791 tons/fed., with an average of 14.67 tons/fed., as mentioned by the yearly book of Economics and Statistics of the Ministry of Agriculture, Egypt.

Onion, like other crops, is attacked by various pathogens in the field as well as in storage, which degrade its quality and yield (Anonymous, 2001). Symptoms of these diseases might not be visible in field but become visible when the pathogen grows under storage conditions. Thereby most onion diseases begin on plants growing in the field and continue to develop on the bulbs during storage and transit, when symptoms become evident (Conn *et al*., 2012). Among these pathogens, *Aspergillus niger* invades bulbs of onions in field or storage whenever they find injured tissues by producing various enzymes or toxins (Srinivasan and Shanmugam, 2006). Also, Fusarium basal rot can occur in field and/or during storage and their losses during storage were greater than losses observed in field (Cramer, 2000). Although neck rot of onion is primarily considered a storage disease, infection starts in the field when the spores from different inoculum sources are blown into a field and settle on mature or injured leaves and necks (Jorjandi *et al.*, 2009). However, bacterial soft rot disease can develop on onions in the field before harvest, after heavy rains and when leaves are drying and developed in storage (Conn *et al*., 2012). The effective control of post-harvest diseases begins with the understanding that these diseases originate in the field (Sadik *et al.*, 2015).

Onion bulbs are highly susceptible to post-harvest rots, caused by micro-organisms particularly fungi during storage period, which have been known to produce toxins causing injuries to human and animal health (Samuel and Ifeanyi, 2015). Several pathogens attack Egyptian onion causing considerable loses in yield, *i.e. Aspergillus niger* (black mould), *Botrytis allii* (neck rot), *Fusarium oxysporum* f. sp. *cepae* (basal rot) and *Erwinia carotovora* sub. sp. *carotovora* (bacterial soft rot) (El-Shehaby *et al.,* 1997 and Hussein *et al.,* 2014). Losses caused by post-harvest rots in onion are greater than is often realized and avoidable between farm gate and consumers (El-Neshawy *et al.,* 2004). These losses may be high because of the favorable weather conditions for the development of the causal pathogens throughout the year (Hussein *et al.,* 2014). About 35-40 % of stored onion is lost due to storage diseases. There are diverse fungal species like *Aspergillus* spp., *Penicillium* spp., *Alternaria* spp., *Fusarium* spp., *Rhizopus* spp., *Colletotrichum* spp. and *Botrytis* spp. As well as bacterial species like *Pseudomonas* spp., *Lactobacillus* spp., *Erwinia* spp. attack onion bulb during the post-harvest storage period. Amongst all *Aspergillus* spp., *A. niger* is especially the most virulent pathogen in the field and storage (Kumar *et al.,* 2015). Post-harvest diseases of onion are due to latent infection from that under field conditions and if these infections are minimized before harvesting, it is possible to reduce the post-harvest losses (Raju and Naik, 2006).

Pre-harvest fungicidal treatments can be an appropriate strategy for controlling onion bulb rots during storage (El-Shehaby *et al.,* 1997 and Rajapakse and Edirimanna, 2002). However, application of fungicides would be harmful for human health due to residual impact issues and increased the resistance of the pathogens, as well as they are not safe over public concern over food and environmental safety (Samuel and Ifeanyi, 2015). Therefore, it is essential to develop strategies to minimize losses during storage by alternative methods like the potent application of plant derived compounds and diverse bio-fungicides (Kumar *et al.,* 2015 and Samuel and Ifeanyi, 2015). The biological control is the alternative method of the fungicides that achieved remarkable success to control the plant pathogens by its rule and with its impact as antagonistic agents (Hussein *et al.,* 2014).

This investigation was undertaken to manage onion bulb rots during storage under pre-harvest treatment with some fungicides as foliar spraying in the field and post-harvest treatment with some biocides before storage and their effects on reducing losses of onion bulb weight during storage intervals.

Materials and Methods

These experiments were conducted to determine the efficacy of some chemical fungicides recommended for controlling downy mildew and purple blotch diseases of onion as pre-harvest treatments and post-harvest treatments with some biocides before storage in controlling onion bulb rots, *i.e.* black mould, basal rot, botrytis neck rot and bacterial soft rot under storage conditions during two successive seasons 2014/2015 and 2015/2016.

Pre-harvest treatment in field:

Field experiments were carried out during two successive growing seasons 2014/2015 and 2015/2016 at Tokh location in Qalubia governorate. Randomized complete block design with three replicates was used and the plot was 3.0 x 3.5 m^2 (10.5 m^2 = 1/400 feddan). Each plot included 6 rows (each 3.0 m length and 50 cm width). Sixty-day-old transplants of onion cultivar Giza 20 were planted per each plot at the recommended spacing 10 cm X 10 cm, within each row on the second week of December. The recommended agricultural practices for onion were used.

Foliar spraying with some fungicides was applied for controlling onion bulb rot diseases mentioned before that start in field and continued or developed during storage. Seven fungicides, *i.e.* Ridomil gold plus 42.5% WP (Mefenoxam + Copper oxychloride) at 200 g/100 liter water, King star up 32% SC (Azoxsystrobin + Propiconazole) at 75 ml/100 liter water, Luna experience 40% SC (Tebuconazole + Fluapyram) at 100 ml/100 liter water, Cobox 50% WP (Copper oxychloride) at 250 g/100 liter water, Tazoline 72% WP (Mancozeb + Metalaxyl) at 250 g/100 liter water, Acrobat Mancozeb 69% WG (Dimethomorph + Mancozeb) at 250 g/100 liter water and Antracol 72% WG (Proineb) at 200 g/100 liter water were used in this study. Non-treated plots (spraying with water) served as control. Foliar spraying was taken at 30^{th}, 20^{th} and 10^{th} day before harvest using a hand operated knapsack sprayer. The recommended harvesting practices for onion crop were always used.

Post-harvest treatment in storage:

Onion bulbs in field trials were harvested after about 5 months from planting (when 50% of the onion neck fallen down). The bulbs were cured in the open air for 2 weeks before storage. After harvest practices, dried bulbs were collected from each pre-harvest treatment and transported to laboratory in order to evaluate the effectiveness of the field treatments under storage conditions plus the biocides as post-harvest treatment.

Five post-harvest treatments, *i.e.* untreated treatment and four biocides namely Bio Arc® (*Bacillus megaterium* 2.5x10^7 cfu/g), Bio Zeid® (*Trichoderma album* 10^7 spores/g), Bio 4 (mixture of four *Bacillus* spp., *i.e. B. megaterium*, *B. subtilis, B. lechnifrmes* and *B. pumolis* 2.5x10^7cfu/g) and Bio Nagi (*Trichoderma asperellum* 10^7 spores/g) were used in this work. Bio Arc® and Bio Zeid® are commercial biocides labeled on different crops in Egypt. However, both Bio 4 and Bio Nagi are still under registration and obtained from Identification of Micro-organisms, Biological Control of Plant Diseases and Evaluation of Bio-fungicides Unit, Plant Pathol. Res. Inst., Agric. Res. Centre, Giza, Egypt.

Apparently healthy, uniform sized bulbs produced from freshly harvested crop from each pre-harvest treatment in the two experimented seasons were sprayed using fine volume atomizer with each of four tested biocides at the rate of 5 g/l. water on all the surfaces of the stored bulbs as equal to give uniform thin wetted layer. Spray with sterile water only served as check treatment.

All the treated bulbs of each storage treatment were left to be air dried for 2 hrs. then collected back in Mesh Bags to the storage at room temperature (28±2°C). Five kilograms bulbs of each treatment were arranged in a randomized complete block design with three replications. Observations on the rots of bulbs were recorded at weekly intervals.

Disease assessments:

By the end of every storage period, bulbs were screened for disease incidence of black mould, basal rot, Botrytis neck rot and bacterial soft rot on regular intervals three and six months after storage. Percentages of rot diseases in bulbs were estimated to the total number of bulbs in each lot of all storage treatments. Lost weight of onion bulbs was also estimated and calculated as follows:

$$\text{\% Lost weight of bulb (Reduction \%) per each treatment} = \frac{\text{Weight of bulbs in zero time (5kg)} - \text{their weight after storage}}{\text{Weight of bulbs in zero time (5kg)}} \times 100$$

Statistical analysis:

The obtained data were statistically analyzed by analysis of variance (ANOVA) using MSTAT-C program version 2.10. The least significant difference (LSD) test (0.05) was used to find out the significance of mean difference of various treatments (Gomez and Gomez, 1984).

Results

1- Effect of pre-plus post-harvest treatments on incidence of onion bulb rots after three and six *months of storage under natural infection, 2014/2015 and 2015/2016 seasons:*

A- Black mold:

Data (Table 1) showed that all pre-plus post-harvest treatments significantly decreased onion black mold after three and six months under storage conditions compared to untreated controls in two successive seasons (2014/2015 and 2015/2016). The most superior combination treatments were Acrobat Mancozeb, combined with Bio Nagi or Bio Zeid and Ridomil gold plus combined with Bio Nagi since they recorded the least incidence (%) of the disease, whereas Cobex plus Bio Arc or Bio 4 were the least effective combinations after three and six months during the two successive seasons. Incidence of onion black mold was always increased with increasing storage intervals from three to six months.

B- Basal rot:

Data (Table 2) illustrated that all treatments applied before plus after harvesting significantly decreased incidence of onion basal rot after three and six months under storage conditions compared to untreated treatments. The lowest incidence of basal rot were recorded with Acrobat Mancozeb combined with Bio Nagi or Bio Zeid, Luna experience combined with Bio Arc after three months during the two seasons tested and Ridomil gold plus combined with Bio Nagi after three months in the second season. On the other hand, Bio Nagi combined with each of Luna experience,

Table 1. Effect of pre-plus post-harvest treatments on incidence of onion black mold after three and six months of storage under natural infection, 2014/2015 and 2015/2016 seasons

season	Pre-harvest treatments	Post-harvest treatments									
		Bio Arc		Bio Zeid		Bio Nagi		Bio 4		Control	
		3M	6M	3M	6M	3M	6M	3M	6M	3M	6M
2014 / 2015	Ridomil gold plus	5.5	7.3	6.0	9.2	3.1	4.5	6.7	9.5	10.8	15.0
	King star	7.6	10.4	6.8	8.3	3.9	5.8	9.1	12.5	12.3	17.4
	Luna experience	8.2	10.8	3.9	5.4	4.8	6.1	9.9	12.0	11.8	15.3
	Cobox	12.4	17.5	9.8	12.3	7.2	10.1	12.6	18.2	18.7	27.6
	Tazoline	6.9	10.3	3.5	6.8	8.2	11.7	10.4	14.6	12.5	17.0
	Acrobat Mancozeb	5.3	8.0	3.1	5.2	2.0	4.8	4.9	7.3	10.7	14.4
	Antracol	5.8	7.5	4.1	6.3	3.6	6.2	5.7	8.2	10.0	15.9
	Control	14.1	18.9	10.2	13.4	12.6	16.0	14.3	20.1	22.3	28.9
	Mean	8.2	11.3	5.9	8.4	5.7	8.2	9.2	12.8	13.6	18.9
2015 / 2016	Ridomil gold plus	6.2	8.5	5.4	8.7	3.5	5.6	7.2	9.4	11.7	16.2
	King star	7.8	9.3	5.9	8.2	4.2	6.7	10.7	13.6	13.6	16.1
	Luna experience	7.9	10.5	4.2	7.1	5.3	7.5	8.7	13.1	13.3	15.4
	Cobox	12.8	15.8	10.4	13.0	8.8	11.5	13.5	20.7	20.9	26.8
	Tazoline	8.1	11.3	4.3	7.5	9.5	13.1	11.6	14.8	14.9	18.2
	Acrobat Mancozeb	4.5	7.3	4.2	6.8	3.1	5.3	5.7	7.5	9.5	13.5
	Antracol	5.2	8.1	3.6	7.5	4.4	7.3	6.8	9.6	11.4	16.7
	Control	13.5	16.3	11.3	13.5	10.9	15.8	15.0	22.6	24.1	30.2
	Mean	8.3	10.9	6.2	9.0	6.2	9.1	9.9	13.9	14.9	19.1

L.S.D. at 5% for:	2014/2015 season		2015/2016 season	
	3M	6M	3M	6M
Pre- plus post-harvest treatments	3.44	4.75	3.71	4.93

*3M: (three months storage) & 6M: (six months storage).

Acrobat Mancozeb or Ridomil gold plus gave the best reductions in the disease incidence after six months during the two seasons tested with some exception, as well as, Luna experience combined with Bio Arc and Bio Zied after six months at the first season. However, Cobex plus Bio 4 was the least effective combination in decreasing disease occurrence after three and six months during the two successive seasons tested. Incidence of onion basal rot was always increased with increasing storage intervals from three to six months.

Table 2. Effect of Effect of pre- plus post-harvest treatments on incidence of onion basal rot after three and six months of storage under natural infection, 2014/2015 and 2015/2016 seasons

season	Pre- harvest treatments	Post-harvest treatments									
		Bio Arc		Bio Zeid		Bio Nagi		Bio 4		Control	
		3M	6M	3M	6M	3M	6M	3M	6M	3M	6M
2014 / 2015	Ridomil gold plus	4.3	5.8	3.8	4.1	2.2	2.9	5.9	6.8	6.4	8.5
	King star	4.8	6.1	2.5	4.9	2.4	4.1	4.3	6.5	6.2	8.7
	Luna experience	1.7	2.9	2.4	3.1	2.7	2.5	3.7	4.8	4.5	6.2
	Cobox	4.8	6.2	3.6	5.8	2.4	4.1	5.7	8.9	9.4	12.1
	Tazoline	4.1	5.9	2.6	3.4	3.0	5.2	5.6	7.1	6.9	9.4
	Acrobat Mancozeb	3.9	6.2	1.5	4.3	1.3	2.9	3.2	5.3	4.8	7.1
	Antracol	3.2	5.3	3.0	5.1	2.9	4.7	3.4	5.8	6.1	8.4
	Control	6.5	8.9	7.0	10.2	6.3	8.5	7.6	10.8	10.3	12.7
	Mean	4.2	5.9	3.3	5.1	2.9	4.4	4.9	7.0	6.8	9.1
2015 / 2016	Ridomil gold plus	3.9	6.9	3.0	4.8	1.9	3.5	5.4	6.9	8.2	10.1
	King star	4.9	7.2	2.3	4.1	2.6	5.0	5.2	7.2	8.0	10.6
	Luna experience	2.3	4.9	2.1	4.3	3.4	5.1	3.6	6.0	6.4	9.5
	Cobox	3.7	5.9	4.3	6.3	2.1	5.0	6.3	10.1	11.2	13.3
	Tazoline	4.2	6.5	3.2	4.8	4.1	6.4	4.9	7.5	9.3	12.3
	Acrobat Mancozeb	3.1	5.8	2.1	5.1	1.7	3.5	4.1	6.2	5.1	6.3
	Antracol	2.4	4.9	3.8	6.2	3.6	5.1	4.5	7.1	7.2	9.3
	Control	5.9	7.8	7.2	9.7	7.5	9.3	9.2	13.2	12.4	14.2
	Mean	3.8	6.2	3.5	5.7	3.4	5.4	5.4	8.0	8.5	10.7

L.S.D. at 5% for:	2014/2015 season		2015/2016 season	
	3M	6M	3M	6M
Pre-plus post-harvest treatments	1.80	2.48	1.38	2.80

*3M: (three months storage) & 6M: (six months storage).

C- Neck rot:

Data presented in Table (3) revealed that incidence (%) of neck rot was increased after six months in storage than three months. The most superior combinations caused the highest reductions in neck rot incidence were Bio Nagi combined with King star, Ridomil gold plus, Tazoline, Luna experience or Acrobat Mancozeb, as well as, Bio Zeid combined with Luna experience or Ridomil gold plus and combined treatment of Bio Arc with Acrobat Mancozeb after storage of three months at the first season. However, combinations between Bio Nagi and King star or Tazoline and Bio Zeid with Ridomil gold plus, Luna experience or Antracol were the best combinations in reducing neck rot after six months at the first season. At the second season, the best combinations after three months of storage were: Bio Zeid combined with Ridomil gold plus, Luna experience or Antracol, Bio Nagi combined with King star and Bio Arc combined with Acrobat Mancozeb. Meanwhile, the best combined treatments after storage of six months were: Bio Zeid combined with Ridomil gold plus or Luna experience, Bio Arc combined with Acrobat Mancozeb and Bio Nagi combined with King star. On the other side, Bio 4 combined with Cobex at the first season or combined Antracol at the second season were the least effective combinations in this respect after three and six months.

Table 3. Effect of pre- plus post-harvest treatments on incidence of onion neck rot after three and six months of storage under natural infection, 2014/2015 and 2015/2016 seasons

season	Pre- harvest treatments	Post-harvest treatments									
		Bio Arc		Bio Zeid		Bio Nagi		Bio 4		Control	
		3M	6M	3M	6M	3M	6M	3M	6M	3M	6M
2014 / 2015	Ridomil gold plus	2.3	3.2	0.8	1.2	0.5	1.7	1.9	3.5	3.7	5.6
	King star	1.9	2.5	1.1	1.6	0.4	0.8	2.6	3.4	4.1	5.8
	Luna experience	1.7	2.6	0.5	1.2	0.7	1.5	2.4	3.2	3.5	5.4
	Cobox	2.9	3.3	1.3	2.1	1.1	2.4	3.6	4.5	5.1	7.8
	Tazoline	1.9	2.7	0.8	1.7	0.6	1.1	1.2	3.4	3.8	4.6
	Acrobat Mancozeb	0.4	1.8	1.0	2.2	0.9	1.7	1.5	2.7	2.6	3.5
	Antracol	1.8	2.7	0.4	1.2	1.1	1.8	1.6	2.9	2.0	3.2
	Control	3.2	4.5	3.1	4.9	1.8	3.4	5.5	6.7	6.4	8.8
	Mean	2.0	2.9	1.1	2.0	0.9	1.8	2.5	3.8	3.9	5.6
2015 / 2016	Ridomil gold plus	1.9	4.2	0.5	1.7	1.2	2.8	2.4	4.3	5.1	7.4
	King star	1.5	3.9	1.4	2.1	0.9	1.7	2.1	4.5	5.9	7.0
	Luna experience	1.6	2.7	0.9	1.5	1.2	2.4	1.8	4.0	4.9	6.7
	Cobox	2.5	4.1	1.6	2.7	1.4	3.2	3.1	4.2	5.3	8.5
	Tazoline	2.3	3.6	1.2	2.4	1.6	2.8	1.8	3.9	5.8	7.8
	Acrobat Mancozeb	0.8	1.4	1.3	2.9	1.5	2.2	2.2	4.1	4.2	5.3
	Antracol	1.2	3.2	0.9	2.0	1.7	2.6	2.5	4.7	3.3	5.8
	Control	3.5	4.9	2.6	4.7	2.5	4.4	4.8	5.9	6.8	9.2
	Mean	1.9	3.5	1.3	2.5	1.5	2.8	2.6	4.5	5.2	7.2

L.S.D. at 5% for:	2014/2015 season		2015/2016 season	
	3M	6M	3M	6M
Pre-plus post-harvest treatments	0.97	1.37	1.00	1.61

*3M: (three months storage) & 6M: (six months storage).

D- Bacterial soft rot:

All treatments applied as pre- plus post-harvesting significantly decreased bacterial soft rot after three and six months under storage conditions during the two seasons tested compared to untreated controls (Table, 4). The superior treatments were: King star combined with Bio Arc or Bio Nagi and Ridomil gold plus combined with Bio Arc or Bio 4 after three and six months during storage conditions at the two successive seasons. While, Cobex combined with Bio Zeid gave the least effective treatment in this respect.

Table 4. Effect of pre- plus post-harvest treatments on incidence of onion bacterial soft rot after three and six months of storage under natural infection, 2014/2015 and 2015/2016 seasons

season	Pre- harvest treatments	Post-harvest treatments									
		Bio Arc		Bio Zeid		Bio Nagi		Bio 4		Control	
		3M	6M	3M	6M	3M	6M	3M	6M	3M	6M
2014 / 2015	Ridomil gold plus	2.6	4.0	7.4	8.3	3.2	4.6	2.5	3.9	11.5	15.7
	King star	0.0	0.0	6.2	8.7	2.3	4.0	4.3	6.1	9.7	12.3
	Luna experience	5.6	8.0	8.9	10.2	5.8	7.7	5.3	6.9	11.3	15.5
	Cobox	6.9	10.8	10.6	15.8	8.5	12.3	7.5	10.2	16.5	22.7
	Tazoline	3.3	5.4	6.2	9.8	5.4	8.3	4.0	6.7	11.6	16.7
	Acrobat Mancozeb	4.7	8.3	8.8	14.2	6.1	9.5	3.8	6.7	12.5	18.4
	Antracol	3.1	5.9	7.8	10.4	5.6	8.8	4.5	6.4	13.4	18.6
	Control	9.1	11.7	11.9	17.4	9.8	14.4	8.4	11.3	19.9	25.3
	Mean	4.4	6.8	8.5	11.9	5.8	8.7	5.0	7.3	13.3	18.2
2015 / 2016	Ridomil gold plus	2.9	5.1	6.9	9.0	4.1	5.7	1.9	4.0	13.2	16.8
	King star	1.2	2.8	5.8	9.4	3.7	5.5	4.2	7.3	11.2	14.5
	Luna experience	6.1	9.2	8.1	10.4	5.7	7.5	5.8	8.0	12.7	14.8
	Cobox	6.2	11.3	11.3	16.5	8.6	11.9	8.7	12.5	18.0	22.8
	Tazoline	4.0	7.2	7.1	10.3	6.3	9.4	5.1	8.3	13.9	18.0
	Acrobat Mancozeb	5.4	7.9	9.3	12.1	7.0	10.2	3.5	7.4	11.8	16.7
	Antracol	4.2	6.3	9.9	11.4	7.3	9.6	5.3	7.4	12.5	17.9
	Control	10.4	13.1	12.7	17.3	10.5	13.1	9.2	13.5	21.3	26.1
	Mean	5.1	7.9	8.9	12.1	6.7	9.1	5.5	8.6	14.3	18.5

L.S.D. at 5% for:	2014/2015 season		2015/2016 season	
	3M	6M	3M	6M
Pre-plus post-harvest treatments	2.91	4.02	3.09	4.16

*3M: (three months storage) & 6M: (six months storage).

2- *Effect of pre- plus post-harvest treatments on reduction in onion bulb weight after three and six months of storage under natural infection:*

A- First season, 2014 /2015:

Results illustrated in Table (5) indicate that reduction in bulb weight of onion significantly affected by using treatments applied as pre- plus post-harvesting after three and six months during storage compared to untreated controls at the first season 2014/2015. The superior combination treatments were Bio Nagi combined with each of King star, Acrobat Mancozeb, Ridomil gold plus, or Antracol and Bio Arc combined with Acrobat Mancozeb or Antracol during the two storage intervals. Whereas, Cobex combined with Bio 4 or Bio Zeid gave the least effective treatments in this respect.

Table 5. Effect of pre- plus post-harvest treatments on reduction in onion bulb weight after three and six months of storage under natural infection, 2014/2015 season

Storage Interval	Pre- harvest treatments	Post-harvest treatments									
		Bio Arc		Bio Zeid		Bio Nagi		Bio 4		Control	
		*BW	R %	BW	R %	BW	R %	BW	R %	BW	R %
Three months storage	Ridomil gold plus	3.94	21.2	3.92	21.6	4.26	14.8	3.82	23.6	3.31	33.8
	King star	3.89	22.2	3.87	22.6	4.32	13.6	3.85	23.0	3.42	31.6
	Luna experience	3.92	21.6	3.78	24.4	3.96	20.8	3.72	25.6	3.61	27.8
	Cobox	3.71	25.8	3.62	27.6	3.82	23.6	3.58	28.4	2.87	42.6
	Tazoline	3.95	21.0	3.76	24.8	3.86	22.8	3.64	27.2	3.41	31.8
	Acrobat Mancozeb	4.22	15.6	3.91	21.8	4.31	13.8	3.92	21.6	3.44	31.2
	Antracol	4.18	16.4	3.82	23.6	4.26	14.8	3.88	22.4	3.11	37.8
	Control	3.63	27.4	3.58	28.4	3.77	24.6	3.35	33.0	2.88	42.4
	Mean	3.93	21.4	3.78	24.4	4.07	18.6	3.72	25.6	3.26	34.9
Six months storage	Ridomil gold plus	3.56	28.8	3.45	31.0	3.71	25.8	3.32	33.6	2.82	43.6
	King star	3.50	30.0	3.41	31.8	3.84	23.2	3.38	32.4	2.91	41.8
	Luna experience	3.65	27.0	3.42	31.6	3.85	23.0	3.40	32.0	2.96	40.8
	Cobox	3.35	33.0	3.19	36.2	3.42	31.6	3.26	34.8	2.28	54.4
	Tazoline	3.62	27.6	3.44	31.2	3.57	28.6	3.37	32.6	2.67	46.6
	Acrobat Mancozeb	3.76	24.8	3.49	30.2	3.82	23.6	3.48	30.4	2.73	45.4
	Antracol	3.78	24.4	3.50	30.0	3.91	21.8	3.53	29.4	2.84	43.2
	Control	3.38	32.4	3.35	33.0	3.46	30.8	3.11	37.8	1.95	61.0
	Mean	3.58	28.5	3.41	31.9	3.70	26.1	3.36	32.9	2.65	47.1

L.S.D. at 5% for:	Three months storage		Six months storage	
	*BW	R %	BW	R %
Pre-plus post- harvest treatments	NS	9.13	1.23	12.11

* BW: Bulb weight (Kg) & R %: Reduction (%)

** Weight of onion bulb in zero time before storage 5.0 kg for each treatment.

B- Second season, 2015/2016:

Most of the applied treatments before plus after onion harvesting gave positive effects on the reduction of bulb weight after three and six months during storage compared to untreated controls at the second season (2015/2016) (Table, 6). The most superior combinations in decreasing reductions were Bio Nagi combined with each of Acrobat Mancozeb, Antracol, King star, or Ridomil gold plus, respectively and Bio Arc combined with Acrobat Mancozeb, or Antracol, respectively during the two storage intervals with few exceptions. Whereas, Cobex combined with Bio 4 or Bio Arc after three and six months and Tazoline combined with Bio Zeid after six months were the least effective combinations in this respect.

Discussion

Post harvest diseases may start before or after harvest. For many post-harvest diseases, they infect the crop in the field shortly before harvest and symptoms were not visible in the field and started to appear under storage conditions. Pre- and post-harvest applications of fungicides or biocides are used to control these diseases (Anonymous, 2012).

Table 6. Effect of pre- plus post-harvest treatments on reduction in onion bulb weight after three and six months of storage under natural infection, 2015/2016 season

Storage Interval	Pre- harvest treatments	Post-harvest treatments									
		Bio Arc		Bio Zeid		Bio Nagi		Bio 4		Control	
		*BW	R %	BW	R %	BW	R %	BW	R %	BW	R %
Three months storage	Ridomil gold plus	3.96	20.8	3.88	22.4	4.10	18.0	3.80	24.0	3.20	36.0
	King star	3.91	21.8	3.80	24.0	4.13	17.4	3.75	25.0	3.35	33.0
	Luna experience	3.87	22.6	3.75	25.0	3.90	22.0	3.72	25.6	3.45	31.0
	Cobox	3.62	27.6	3.76	24.8	3.85	23.0	3.61	27.8	2.72	45.6
	Tazoline	3.87	22.6	3.62	27.6	3.74	25.2	3.63	27.4	3.11	37.8
	Acrobat Mancozeb	4.19	16.2	3.85	23.0	4.23	15.4	3.82	23.6	3.21	35.8
	Antracol	4.12	17.6	3.79	24.2	4.20	16.0	3.90	22.0	2.98	40.4
	Control	3.52	29.6	3.45	31.0	3.66	26.8	3.25	35.0	2.45	51.0
	Mean	3.88	22.4	3.74	25.3	3.98	20.5	3.69	26.3	3.06	38.8
Six months storage	Ridomil gold plus	3.50	30.0	3.37	32.6	3.62	27.6	3.34	33.2	2.74	45.2
	King star	3.47	30.6	3.35	33.0	3.72	25.6	3.36	32.8	2.76	44.8
	Luna experience	3.35	33.0	3.42	31.6	3.61	27.8	3.31	33.8	2.88	42.4
	Cobox	3.23	35.4	3.27	34.6	3.34	33.2	3.21	35.8	2.14	57.2
	Tazoline	3.53	29.4	3.36	32.8	3.41	31.8	3.29	34.2	2.46	50.8
	Acrobat Mancozeb	3.69	26.2	3.42	31.6	3.75	25.0	3.30	34.0	2.65	47.0
	Antracol	3.62	27.6	3.37	32.6	3.84	23.2	3.36	32.8	2.59	48.2
	Control	3.14	37.2	3.21	35.8	3.25	35.0	2.95	41.0	1.63	67.4
	Mean	3.44	31.2	3.35	33.1	3.57	28.7	3.27	34.7	2.48	50.4

L.S.D. at 5% for:	Three months storage		Six months storage	
	*BW	R %	BW	R %
Pre-plus post-harvest treatments	1.34	9.74	1.18	12.93

* BW: Bulb weight (Kg) & R %: Reduction (%)

** Weight of onion bulb in zero time before storage 5.0 kg for each treatment.

Post-harvest application of fungicides or biocides can inhibit fungal activity of a number of micro-organisms, which improved shelf-life in a number of fruits and vegetables (Ram *et al.,* 2011). Post-harvest diseases of onion during storage conditions may be due to latent infection before harvest or after harvest before storage, as well as, due to secondary infection during storage conditions. Therefore, if these infections are minimized before harvest or after harvest before storage by different treatments it is possible to reduce the post harvest losses of onion (Raju and Naik, 2006).

The most onion diseases begin on plants growing in the field and continue to develop on the bulbs during storage and transit (Conn *et al.,* 2012 and Sadik *et al.,* 2015). Several pathogens attack Egyptian onion crop causing considerable losses in bulb yield such as *Aspergillus niger* (black mould), *Botrytis allii* (neck rot), *Fusarium oxysporum* f. sp. *cepae* (basal rot) and *Erwinia carotovora* sub. sp. *carotovora* (bacterial soft rot) (Hussein *et al.,* 2014). In the present investigation, black mould and bacterial soft rot recorded the highest incidence of bulb rots during three and six months of storage at 2014/2015 and 2015/2016 seasons, followed by basal rot, while neck rot recorded the least one in this respect. Gupta and Verma (2002) revealed that about 35-40% of onion bulbs were lost due to damages caused by different diseases. A number of micro-organisms are responsible for bulb rots, but fungi are the main causal agent responsible for pre- and post-harvest losses (Samuel and Ifeanyi, 2015). However, black moulds are frequently isolated from stored diseased bulbs of local onion cultivars in Egypt (Hussain *et al.,* 1977). Among the pathogens of these diseases, *Aspergillus niger* is able to produce mycotoxin which reduces the quality and quantity of food products and feed-stuff which is a potent hepatic carcinogen in humans and animals (Soliman and Badeaa, 2002). Also, bacterial soft rot is considered as one of the limiting factors of onion production in some areas of the world as well as in Egypt (Abdalla *et al.,* 2013). The effect of this disease is more pronounced in the developing countries where appropriate storage facilities are lacking (Abdalla *et al.,* 2013). Therefore, onion production has been significantly affected due to soft rot disease caused by *Erwinia* spp. and *Burkholderia* spp. (Abdalla *et al.,* 2013) in Egypt.

Most of the applied treatments as pre- and post-harvest significantly decreased bulb rots, *i.e.* black mould, basal rot, neck rot and bacterial soft rot after three and six months during storage compared to untreated controls. The best combination between pre- plus post- harvest treatments in decreasing bulb rots were: Bio Nagi combined with Ridomil gold plus, King star, Acrobat Mancozeb, Luna experience or Antracol, respectively, and Bio Arc combined with each of King star, Acrobat Mancozeb, Ridomil gold plus or Antracol, respectively. Also, Bio Zeid combined with Tazoline, Acrobat Mancozeb, Antracol, King star or Ridomil gold plus, respectively and Bio 4 combined with Acrobat Mancozeb, Antracol or Ridomil gold plus, respectively recorded this positive effect after three and six months of storage in most cases. In contrast, Cobex combined with Bio 4 was the least effective combination. Combination between fungicides and biocides or any other treatments may be useful against bulb rots control. In this respect Abou-Zeid *et al.* (2011) indicated that biocides (Bio Arc or Bio Zeid) with solarization gave acceptable results in controlling the major soil-borne diseases of tomato (fungal pathogens & root-knot nematodes) and the best increase of tomato yield. Also, Srinivasan and Shanmugam (2006) reported that, carbendazim was found to be the most effective fungicide for controlling black mold rot of onion when applied as pre-harvest foliar spray or as a post-harvest dip combining with Sulphur dioxide treatment as a post-harvest fumigation.

Several investigators studied the effect of pre-harvest treatment of systemic, non-systemic fungicides for controlling onion bulb rots during storage and reported that, storage losses due to fungi could be reduced up to 40% by spraying fungicides like carbendazim as pre- harvest application two weeks before harvesting or 30, 20 and 10 days before harvest (Rajapakse and Edirimanna, 2002, Raju and Naik, 2006, and Srinivasan and Shanmugam, 2006). Several fungicides have been found effective against pathogenic fungi responsible for fungal rots on onion in storage and in field conditions (Wani and Taskeen-Un-Nisa, 2011). The systemic or non-systemic fungicides may be having different modes of action, such as respiration inhibition (Kim and Xiao, 2010), inhibits the cell growth of fungi by promoting inhibiting osmotic signal transduction or denature proteins and enzymes (Babdoost, 2012). Also, copper hydroxide as non-systemic fungicide acts both as a fungicide and bactericide. It is used as a pre-harvest fungicide to prevent diseases in a number of fruits and vegetables (Anonymous, 2012). The serious problems in using the synthetic fungicides to control plant diseases were their toxicity and development of pathogen resistance, therefore, we need to find alternative sources for disease management (Sibi *et al.,* 2013).

The application of different synthetic fungicides for controlling onion post-harvest diseases is a common practice but due to their toxicity, formulations originated from micro-organisms or plants to control fungal pathogens are needed (Elad, 2000). Only a few micro-organisms have been fully commercialized for the control of soil and foliar plant pathogens (Fravel *et al*., 1999). The different *Trichoderma* species were found to suppress the growth of *Botrytis allii* under storage conditions and *T. viride* and *T. harzianum* caused the highest reduction (Hussein *et al*., 2014). The fungi biocontrol, including the extensively studied *Trichoderma* spp., have been reported to reduce infection or reproduction of many pathogens (Khalifa *et al.,* 2013 and Mahmoud *et al.* 2013). Reino *et al.* (2008) reported that *Trichoderma* spp. produce different secondary metabolites with antibiotic activity which have been classified in different groups based on their biosynthetic origin or their chemical structure. They, however, include non-volatile (peptaibols) and volatile compounds (simple aromatic metabolites, terpenes, the isocyano metabolites, some polyketides, butenolides and pyrones). On the other hand, *Bacillus* spp. protect plants against a wide range of pathogens such as bacterial onion soft rot and the potential for commercial utilization is promising (Abdalla *et al*., 2013). The biological control in field and/or storage against decay using a microbial antagonist have been developed as potential alternatives to chemicals or as part of integrated crop management systems to reduce the input of pesticides and residues on post-harvest fruits and crops (Sadik *et al.,* 2015). However, biological control in a combination of several modes of action, viz. competition, restraint of pathogen enzymes, and induced resistance, is effective in controlling diseases (Elad, 2000). It has already become evident that there is a considerable potential in this for organism production and an exciting promise in its use for biological control (Pandya and Saraf, 2010).

Bulb rots are a common cause of onion loss during storage (Ko *et al.* 2002). In general, the losses due to reduction in weight reached about 35-40 % due to damage caused by storage diseases (Samuel and Ifeanyi, 2015). Reduction in onion bulb weight significantly affected by using the tested treatments applied as pre- plus post-harvesting after three and six months during storage. Most of these treatments significantly reduced the weight loss resulting from bulb rots in storage and increased storage intervals to six months. The most superior combinations between pre- and post-harvest treatments against bulb rots, in most cases were Bio Nagi plus King star, Acrobat Mancozeb, Ridomil gold plus, or Antracol, respectively, and Bio Arc plus Acrobat Mancozeb or Antracol, respectively during the two storage intervals. While, Cobex combined with Bio 4 or Bio Zeid were the least effective combinations in this respect.

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إدارة أعفان البصل في المخزن باستخدام
معاملات المكافحة قبل وبعد الحصاد

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يصيب البصل العديد من أمراض أعفان المخزن مثل العفن الأسود وعفن القاعدة وعفن الرقبة والعفن الطري البكتيري وتسبب هذه الأمراض نقصا في وزن الأبصال أثناء التخزين. وقد سجلت أمراض العفن الأسود والعفن البكتيري أعلى نسبة إصابة في المخزن تلاه عفن القاعدة بينما كان عفن الرقبة الأقل في هذا الصدد خلال فترات التخزين لمدة 3 و 6 شهور في العامين المتتاليين 2015/2014 و 2016/2015. أظهرت معظم معاملات المبيدات المستخدمة رشا قبل الحصاد مع معاملات ما بعد الحصاد وقبل التخزين ببعض المبيدات الحيوية نقصا معنويا في حدوث الإصابة بأعفان المخزن. وكانت المعاملات المشتركة الأكثر تفوقا هى المعاملة المشتركة للمبيد الحيوي بيو ناجي مع كنج ستار وأكروبات مانكوزيب والريدوميل جولد بلس أو الأنتراكول والمبيد الحيوي بيو أرك مع مبيدات أكروبات مانكوزيب أو الأنتراكول على الترتيب. أظهرت المعاملات المشتركة للمبيدات الكيماوية والحيوية المختبرة ما قبل وما بعد الحصاد تأثيرا معنويا إيجابيا في تقليل الفقد في وزن الأبصال.