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Management of bulb rot of onion caused by *Erwinia carotovora* pv. *carotovora*

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Abstract
The bulb rot caused by *Erwinia carotovora* pv. *carotovora* is major important disease of onion is difficult to control without application of bactericides and fungicides respectively. *Erwinia carotovora* pv. *carotovora* causes 40 to 80% losses in onion. In present investigation studies were undertaken to manage bulb rot disease of onion through the use of bactericide and fungicides. Efficacy of different chemicals was tested by filter paper disc diffusion method against *Erwinia carotovora* pv. *carotovora*. Maximum growth inhibition of *Erwinia carotovora* pv. *carotovora* recorded in copper oxychloride @ 0.25% + streptomycin @ 200 ppm (23.00 mm), followed by streptomycin @ 200 ppm (18.00 mm). Under field condition, treatment with bulb dip in copper oxychloride @ 0.25% + streptomycin sulphate @ 200 ppm + spraying with copper oxychloride @ 0.25% was found most effective treatment against bulb rot of onion as it recorded minimum disease incidence (19.67%) with maximum disease control (53.46%). Maximum seed yield obtained in treatment with bulb dip copper oxychloride @ 0.25% + streptomycin 200ppm + spraying with mancozeb @ 0.25% + carbendazim @ 0.10% + copper oxychloride @ 0.25% i.e 1022 kg/ha which was found significantly superior over rest of the treatments.

Keywords: *Erwinia carotovora* pv. *carotovora*, bulb rot, onion, management etc.

Introduction
Onion (*Allium cepa* L.) is one of the oldest bulb crops belongs to Amaryllidaceae family. The genus Allium comprises over 700 species which can be found throughout the tropical, temperate and sub-temperate regions of the world (Fritsch and Friesen, 2002) [12]. There are five important species of Allium of which the onion (*Allium cepa*) is the major cultivated species grown all over the world (Messiaen 1994) [19]. According to Vavilov (1951) [29] the primary center of origin lies in central Asia. Among vegetables, onion often called as "queen of kitchen" is one of the oldest known and an important crop. Onion a bulbous biennial herb, is one of the most important vegetable crop grown throughout world and in India. As a vegetable and spice, it is used both as tender and mature bulb.

In the world, onion is attacked by 66 diseases including 10 bacterial, 38 fungal, 6 nematode, 3 viral, 1 mycoplasmal, 1 parasitic plant and 7 miscellaneous diseases and disorders (Schwartz, 2010) [26]. Among the diseases, bulb rot (*Erwinia carotovora* pv. *carotovora*) is the the most destructive disease, commonly prevailing in almost all onion growing pockets of the India, which causes heavy loss in onions under field conditions as well as in storage. Now days these disease threaten to the onion seed and bulb production in India. Bulb rot losses may be occurs in field or after harvest, during transport, or marketing. *Erwinia* caused 40 to 80% losses in different crops such as onion, *Aloe Vera*, potato, carrot, ornamental and fruit crops etc. (Anonymous, 2006) [6].

The bacteria chiefly attack succulent, tender tissues of storage organ such as fleshy bulb, tubers, fruits, roots, corms & rhizomes as well as bud, stem, petiole & leaf, stalk tissues. Rot bacteria pose constant threat because of their extensive host range and wide spread distribution. In view of this present investigation was carried out to select the best management practice for bulb rot of onion caused by *Erwinia carotovora* pv. *carotovora* at Department of Plant Pathology and Department of Vegetable Science, College of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

Methods and Material
Collection of disease sample
Naturally infected onion showing typical well-developed symptoms of bulb rot and purple blotch were collected from the experiment field, located at Department of Vegetable Science, College of Horticulture Dr. PDKV Akola.

Isolation of *Erwinia carotovora* pv. *carotovora*

Isolation of bacterial pathogen was made from diseased bulb collected from field by streaking method. The nutrient agar (NA) medium was used as basal medium for the *in-vitro* studies and maintenance of pure culture of *Erwinia carotovora* pv. *carotovora* in slants. (Al-Jeboory et. al., 2010) [4] Growth of organism was observed regularly and maintained on NA slants.

Purification and maintenance of the culture

Resulting bacterial colonies were selected from each NA medium plate and re-streaked the bacteria on to a fresh NA plate and these plates were incubated at 28 $\pm$ 2^0C for 24 hr. The single colonies developed, were transferred in NA medium slants and the pure cultures so obtained were stored in refrigerator at 4^0C for further studies.

Identification of pathogens

The isolate of *Erwinia carotovora* pv. *carotovora* were identified on the basis of their morphological properties like colony colour, shape, size and pigmentation and biochemical tests like Gram reaction, KOH test, catalase test, potato soft rot test, gelatin liquification test, urease production test, growth in 5% Nacl test, H_2S production test, indole production test, oxidase test and Methyl red test, were carried out for biochemical confirmation of *Erwinia carotovora* pv. *carotovora*.

Pathogenicity test

Bulb and soil inoculation methods were carried to test the pathogenicity of *Erwinia carotovora* pv. *carotovora.* Plastic pots having 1 Kg capacity were disinfected with the help of denatured spirit. Sterilized potting mixture with bacterial culture suspension (3 X 10^{-6} CFU/ml) of test pathogen 100 ml was filled in the pot. The onion bulbs (cultivar Akola safed) were inoculated by dipping in bacterial suspension of *Erwinia carotovora* pv. *carotovora* and these inoculated bulbs were planted in the pot. The uninoculated pot and bulb served as control. The pots were watered as an when required and observation was recorded an appearance of disease symptoms on growing plant. The reisolation was made to confirm the identity of pathogen associated with disease symptoms so as to prove the Koch's postulate.

In-*vitro* evaluation of chemicals against *Erwinia carotovora* pv. *carotovora*

The sensitivity of different antibiotics and fungicides against *Erwinia carotovora* pv. *carotovora* was studied using Inhibition zone technique. The bacterium was multiplied by inoculating the culture into 50 ml of nutrient broth taken in flask. The inoculated flasks were incubated at 30^0C for 72 hours. The bacterial suspension was then added to the lukewarm nutrient agar medium (1000 ml). The added medium was poured into the sterilized Petri-plates and plates were allowed to solidify. The bactericides were prepared at different concentrations. Filter paper disc of five mm diameter were cut, placed in Petri-plate and autoclaved. Then filter paper discs were soaked in the respective chemical concentrations for 15 min and transferred onto the surface of medium in the Petri-plates. Four discs in each plate, the paper disc without chemical (sterilized distilled water) served as a control. The plates were then incubated at 30^0C for 72 hours.

Table 1: List of chemicals used.

S. No.	Chemical name	Trade name	Company	Conc. (%)
1	Mancozeb 75% WP	Indofil M-45	Indofil Industries Ltd.	0.25
2	Carbendazim 50%WP	Bavistin	BASF, India Ltd.	0.10
3	Copper oxychloride 50% WP	Blitox 50	Syngenta India Ltd.,	0.25
4	Streptomycin	Ambistryn-s	Abbott Healthcare Pvt. Ltd	200 ppm

Treatment details

Table 2: *In-Vivo* Treatments for management of bulb rot.

Tr. No.	Treatment Name	Concentration
Bulb dip treatments for bulb rot -		
T_1	Copper oxychloride	0.25%
T_2	Streptomycin	200 ppm
T_3	Copper oxychloride + Streptomycin	0.25% + 200 ppm
Spraying treatments for purple blotch -		
T_4	Mancozeb + Carbendazim	0.25% + 0.10%
T_5	Copper oxychloride	0.25%
T_6	Mancozeb + Carbendazim + Copper oxychloride	0.25% + 0.10% + 0.25%
Bulb dip + spraying treatments for bulb rot and purple blotch -		
T_7	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim)	0.25% + 200 ppm + 0.25% + 0.10%
T_8	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Copper oxychloride)	0.25% + 200 ppm + 0.25%
T_9	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim + Copper oxychloride)	0.25% + 200 ppm + 0.25% + 0.10% + 0.25%
T_{10}	Control	-

Table 3: *In-Vitro* Treatments

Tr. No.	Treatment Name	Conc.
T_1	Copper oxychloride	0.25%
T_2	Streptomycin	200ppm
T_3	Copper oxychloride + Streptomycin	0.25% + 200ppm
T_4	Copper oxychloride + Carbendazim	0.25% + 0.10%
T_5	Copper oxychloride + Mancozeb	0.25% + 0.25%
T_6	Carbendazim	0.10%
T_7	Mancozeb	0.25%
T_8	Carbendazim + Mancozeb	0.10% + 0.25%
T_9	Mancozeb + Streptomycin	0.25% + 200ppm
T_{10}	Carbendazim + Streptomycin	0.10% + 200ppm
T_{11}	Control	-

Per cent incidence of disease

Observations of disease incidence were recorded at 15 days intervals from date of planting up to harvesting**.** The per cent disease incidence was calculated according to the formula:

$$\text{Per cent incidence} = \frac{\text{No. of plants showing disease symptoms}}{\text{Total no. of plants observed}} \times 100$$

Per cent disease intensity

The observation on leaf spot infection were recorded at 90 DAP and continue upto harvesting at 15 days interval by selecting two leaves each from top, middle and lower portion of the plant. The observations were recorded on the basis of 0-5 scale (Sharma, 1986) [27].

$$\text{Percent Disease Intensity} = \frac{\sum \text{of all numerical ratings}}{\text{(PDI) Total number x Maximum ratings of leaves examine}} \times 100$$

Seed yield (kg/plot)

Seed yield was recorded from each plot. Seed weighed properly and converted to kg/ha. The data obtained from all the experiments were statistically analyzed following the standard methods (Gomez and Gomez, 1984) [13].

Results and Discussion

Collection of diseased samples

Naturally infected diseased samples of bulb rot was collected from experiment field located at Department of Vegetable Science, College of Horticulture, Dr. P.D.K.V., Akola during the study.

Isolation and identification of *Erwinia carotovora* pv. *carotovora*

The causal organism *Erwinia carotovora* pv. *carotovora* was isolated from infected bulb showing typical symptoms. Isolation was done by streaking method on NA medium. Well separated single colony was picked and streaked on NA medium at 27^0C for 48 hours.

The pure colonies obtained were again streaked in slants. The culture so obtained were stored in the refrigerator at 4^0C, which served as a stock culture for further studies. The culture was renewed by sub-culturing once in a fortnight nutrient agar slants**.**

Morphological and biochemical characteristics

The results of the various morphological characters of *Erwinia carotovora* pv. *carotovora* are given in table 5. The bacterium is a rod shaped facultatively anaerobic, gram negative and peritrichously flagellated.

Table 4: Morphological characteristics of *Erwinia carotovora* pv. *Carotovora*

S. No.	Properties	Morphological characters
1	Colony shape	Round and convex
2	Colony colour	White-Creamy
3	Pigmentation	Yellow
4	Cell shape	Straight rod
5	Arrangement	Single

Dickey (1979) [10] and Fahy and Hayward (1983) [11] reported that *Erwinia carotovora* pv. *carotovora* were gram –ve, straight rod-shaped cell and showed initially creamy coloured colonies and later yellow pigmentation. Ali *et al*. (2014) [2], Prajapat (2013) [23] and Rashid *et al.* (2013) [25] reported rod shape of the bacterium where as Mohammad and Selman (2013) recorded rod shape and having smooth, convex, white circular creamy colonies of the bacteria. In present investigation also, the similar morphological properties of the bacteria were recorded, thus confirmed the findings.

Biochemical properties

The isolate of *Erwinia carotovora* pv. *carotovora* showed negative reaction for gram reaction and urease production test. However, positive towards the KOH test, catalase test, potato soft rot test, gelatin liquification test, growth in 5% Nacl test, H_2S production test, indole production test, methyl red test and oxidase test. Table 6.

Table 5: Biochemical properties of *Erwinia carotovora* pv. *Carotovora*

S. No.	Biochemical properties	Reaction of isolate
1	Gram reaction	-ve
2	KOH test	+ve
3	Catalase test	+ve
4	Potato soft rot test	+ve
5	Gelatin liquification test	+ve
6	Urease production test	-ve
7	Growth in 5% Nacl test	+ve
8	H_2S production test	+ve
9	Indole production test	+ve
10	Oxidase test	+ve
11	Methyl red test	+ve

Positive reaction = +ve
Negative reaction = -ve

The present results of respected biochemical test of *Erwinia carotovora* pv. *carotovora.* are similar to Rahman *et al*. (2017) [24] who recorded negative result for gram staining and positive reaction for catalase, potato soft rot, gelatin liquification, methyl red, indole production, growth in 5% NaCl, The –ve gram reaction and positive biochemical test of catalase, gelatin liquification and acid and gas production in respect of *Erwinia carotovora* was also reported by Mohammad and Selman (2013) [20] and Ali *et al.* (2014) [2].

Costa *et al*. (2006) [9] recorded that *Erwinia carotovora* positive to catalase activity and gelatin liquification test. Alvarado *et al.* (2011) [5] recorded that *Erwinia carotovora* is gram negative and catalase positive. Achbani *et al.* (2014) [1] reported that *Erwinia carotovora* were identified by biochemical test including gram staining, catalase, gelatin liquification test, and H_2S production test.

Pathogenicity test and symptoms

Pathogenicity test were conducted by using onion bulbs. *Erwinia carotovora* pv. *carotovora* was observed to be pathogenic to, healthy onion plant by artificial inoculation.

The initial small watery lesions on leaf base were observed after 2-3 days of inoculation. The bulb rotting symptoms were observed on leaves after 5 to 7 days in the form of yellowing of leaves. Reisolation from infected bulb/ plant yielded the same pathogen where as control plants remained healthy. Thus, *Erwinia carotovora* pv. *carotovora* was found pathogenic and caused bulb rot of onion confirming the Koch's postulates. In advanced stage, rotting of whole plants lead to death of plants after 15-17 days.

The pathogenic nature of *Erwinia carotovora* were observed by Achbani *et al*. (2014) [1] and Yanez-Morales (2003) [30] in the form of development of bulb rot symptoms after five days of incubation of onion bulbs by *Pectobacterium* spp. Pathogenicity test of soft rot pathogen in other crop have also been reported by Kumar *et al*. (2011) [17] and Rashid *et al*. (2013) [25].

Symptoms of bulb rot

Symptoms were observed on bulb and leaf. The above ground portion of infected plants appeared weak, thrifty with pale yellow lustreless leaves with marginal necrosis or scorching in older leaves. The plants appeared dwarf and such plants when uprooted along with bulb, showed rotting, tissue becoming soft. Bulb rot symptoms were noticed at the base of central leaves of onion plant in field condition, longitudinal sections revealed that lesions developed downward and the inner layers of bulb also appeared macerated. Onion bulb exhibited water soaking or yellowish-brown rot symptoms. (Achbani *et al*., 2014 and Palacio-Bielsa, 2007) [1, 21]. Infection has been observed at the inner part of the onion bulb in the neck region and the decay gradually invades the whole bulb and affected part become slimy and gives offensive odour. In the early state of bulb infection, the older leaves become severaly decayed and all the leaves die (Yanez-Morales 2003) [30]. Symptoms on the same line due to *Erwinia* spp. have been reported earlier by Mohammad and Selman (2013) [20] and Bhat *et al*. (2010) [8] in Potato, Banana and other tuber crops where soft rot disease caused by Erwinia *carotovora* pv. *carotovora* showed small water-soaked lesions, which enlarge rapidly, affected part become slimy and soft rot accompanied by a characteristically offensive odour.

***In-vitro* efficacy of different chemical treatments against *Erwinia carotovora* pv. *carotovora* by filter paper disc diffusion method**

The filter paper disc diffusion method was employed to test the efficacy of different chemicals against *Erwnia carotovora* pv. *carotovora.* Result are presented in Table 7, Fig 1.

The significant differences in zone of inhibition was recorded among various treatments. Maximum zone of inhibition was recorded by copper oxychloride @ 0.25% + streptomycin @ 200 ppm (23.00 mm) followed by streptomycin @ 200 ppm (18.00 mm), copper oxychloride @ 0.25% (16.25 mm), mancozeb @ 0.25% + streptomycin @ 200 ppm (11.45 mm), carbendazim @ 0.1% + streptomycin @ 200 ppm (10.50 mm) and copper oxychloride @ 0.25% + mancozeb @ 0.25% (9.70 mm). Where as treatments having only fungicide or combination of two fungicide *viz.* mancozeb @ 0.25%, carbendazim @ 0.10%, mancozeb @ 0.25% + carbendazim @ 0.10% and copper oxychloride @ 0.25% + carbendazim @ 0.10% showed no zone of inhibition against *Erwnia carotovora* pv. *carotovora.*

Among the fungicides and antibiotic evaluated by filter paper disc method, copper oxychloride @ 0.25% + streptomycin @ 200 ppm were found significantly superior over remaining chemicals for inhibiting the bacteria.

The highest efficacy might be due to diffusion of chemical in media resulting the restriction of bacterial growth. These results support the finding of Paresh *et al*. (2011) [22] who observed streptomycin (300 ppm) and copper oxychloride (500 ppm) was effective antimicrobial compound against *Erwnia carotovora* inhibiting 20.47% and 20.14% growth respectively. Bhagat (2015) [7] also found that copper oxychloride + streptomycin sulphate is highly effective against *Erwinia carotovora* pv. *carotovora.* Rashid *et al*. (2013) [25] observed that copper-based compound, copper oxychloride (0.2%) was highly effective to suppress the bacterial growth of *Erwinia carotovora* pv. *carotovora.* Thammaiah *et al*. (2006) [28] who reported positive activity of streptomycin sulphate and copper compounds against *Erwnia* spp. in calla lilies.

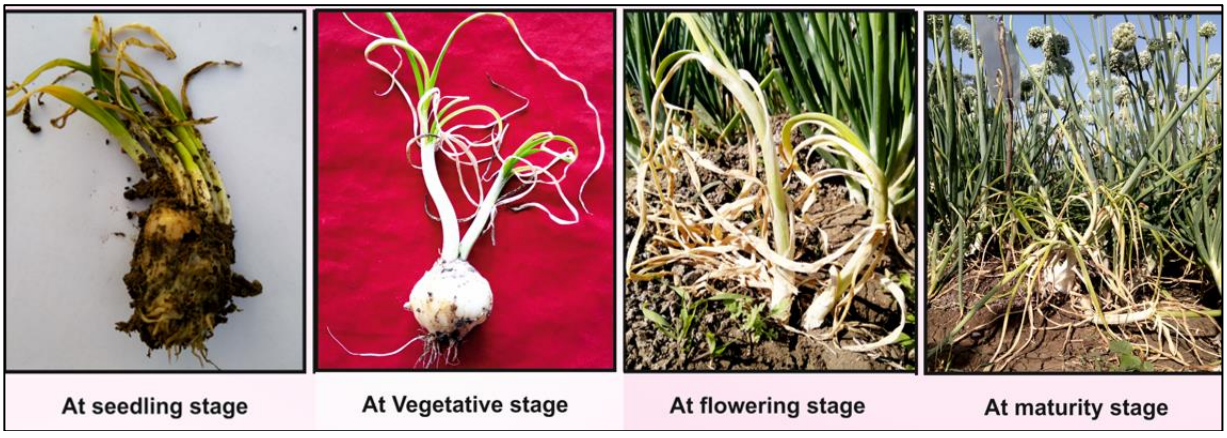

Fig 1: Different symptoms of bulb rot at different growth stages in field

Table 6: *In-vitro* efficacy of different chemical treatments against *Erwinia carotovora* pv. *carotovora* by filter paper disc diffusion method

Tr. No.	Treatment Name	Conc.	Mean inhibition zone (mm)
T_1	Copper oxychloride	0.25%	16.25
T_2	Streptomycin	200 ppm	18.00
T_3	Copper oxychloride + Streptomycin	0.25% + 200 ppm	23.00
T_4	Copper oxychloride + Carbendazim	0.25% + 0.10%	0.00
T_5	Copper oxychloride + Mancozeb	0.25% + 0.25%	9.70
T_6	Carbendazim	0.10%	0.00
T_7	Mancozeb	0.25%	0.00
T_8	Carbendazim + Mancozeb	0.10% + 0.25%	0.00
T_9	Mancozeb+ Streptomycin	0.25% + 200 ppm	11.45
T_{10}	Carbendazim + Streptomycin	0.10% + 200 ppm	10.50
T_{11}	Control	-	0.00

Effect of different chemical treatments on bulb rot of onion in field condition

The effect of different chemicals in controlling the bulb rot of onion were evaluated under field conditions, during *rabi* 2018-19. Disease incidence after planting was found significant over control and ranged from 19.67% to 30.03%. The most effective treatment was (T8) bulb dip (copper oxychloride @ 0.25% + streptomycin @ 200 ppm) + spraying with (copper oxychloride @ 0.25%) recorded minimum disease incidence i.e 19.67 per cent and showed maximum disease control (53.46 per cent) which was followed by treatments (T9) bulb dip (copper oxychloride @ 0.25% + streptomycin @ 200 ppm) + spraying with (mancozeb @ 0.25% + carbendazim @ 0.10% + copper oxychloride @ 0.25%), then (T3) bulb dip (copper oxychloride @ 0.25% + streptomycin @ 200 ppm), and (T7) bulb dip (copper oxychloride @ 0.25% + streptomycin @ 200 ppm) + spraying with (mancozeb @ 0.25% + carbendazim @ 0.10%) that showed 20.10, 20.77, 21.80 per cent disease incidence and 52.44, 50.86, 48.42 per cent disease control respectively. These treatments followed by (T2) streptomycin @ 200 ppm and (T3) copper oxychloride @ 0.25% which showed 24.17, 30.03 per cent disease incidence and 42.81, 28.95 per cent disease control respectively.

The result obtained under field condition correlates with the finding of Mallikarjun *et al.* (2017) [18] reported that drenching and foliar spray of copper oxychloride 50WP at 3g/l + streptomycin sulphate 0.5g/l at 15 days interval, beginning from 15 days after planting was found most effective and recorded lowest soft rot disease incidence. Kapoor (1999**)** [14] recommended steptocyclin in combination with copper oxychloride for control of soft rot diseases caused by *Erwinia carotovora* pv. *carotovora*. Knauss and Miller (1972) [16] recommended streptomycin to provide adequate control of *Erwinia carotovora* under field condition. Rashid *et al*. (2013) [25] observed that copper-based compound, copper oxychloride (0.2%) was highly effective to suppress the bacterial growth of *Erwinia carotovora* pv. *Carotovora*

Fig: Pathogenicity of *Erwinia carotovora* pv. *carotovora* on onion plant *in vitro*

Table 7a: Effect of different chemical treatments on bulb rot incidence of onion under field condition..

Tr. No.	Treatment Name	Conc.	15 days after planting		30 days after planting		45 days after planting		60 days after planting	
			Per cent disease incidence	Per cent disease control	Per cent disease incidence	Per cent disease control	Per cent disease incidence	Per cent disease control	Per cent disease incidence	Per cent disease control
Bulb dip for soft rot										
T_1	Copper oxychloride	0.25%	7.50	46.54	11.50	42.98	17.00	33.85	21.10	32.43
T_2	Streptomycin	200 ppm	3.33	76.26	8.43	58.20	12.03	53.19	16.00	48.76
T_3	Copper oxychloride + Streptomycin	0.25% + 200 ppm	2.50	82.18	6.23	69.11	9.33	63.69	13.50	56.77
Spraying for purple blotch										
T_4	Mancozeb + Carbendazim	0.25% + 0.10%	13.43	4.27	19.43	3.66	24.00	6.61	31.03	0.64
T_5	Copper oxychloride	0.25%	14.00	0.21	20.13	0.19	25.07	2.45	28.40	9.06
T_6	Mancozeb + Carbendazim + Copper oxychloride	0.25% + 0.10% + 0.25%	13.23	5.70	19.20	4.80	23.47	8.67	30.07	3.71
Bulb dip + Spraying for soft rot and purple blotch										
T_7	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim)	(0.25% + 200 ppm) + (0.25% + 0.10%)	3.00	78.61	6.67	66.93	10.00	61.08	13.97	55.26
T_8	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Copper oxychloride)	0.25% + 200 ppm + 0.25%	2.83	79.82	6.03	70.10	8.33	67.58	11.7	62.53
T_9	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim + Copper oxychloride)	0.25% + 200 ppm + 0.25% + 0.10% + 0.25%	2.17	84.53	7.17	64.45	9.17	64.31	12.30	60.61
T_{10}	Control	-	14.03	-	20.17	-	25.70	-	31.23	-

Table 7b: Effect of different chemical treatments on bulb rot incidence of onion under field condition

Tr. No.	Treatment Name	Conc.	75 days after planting		90 days after planting		105 days after planting		120 days after planting	
			Per cent disease incidence	Per cent disease control	Per cent disease incidence	Per cent disease control	Per cent disease incidence	Per cent disease control	Per cent disease incidence	Per cent disease control
Bulb dip for bulb rot										
T_1	Copper oxychloride	0.25%	25.57	28.23	28.23	29.47	30.03	27.63	30.03	28.95
T_2	Streptomycin	200 ppm	19.67	44.79	23.00	42.54	24.17	41.75	24.17	42.81
T_3	Copper oxychloride + Streptomycin	0.25% + 200 ppm	16.77	52.93	19.33	51.71	20.77	49.95	20.77	50.86
Spraying for purple blotch										
T_4	Mancozeb + Carbendazim	0.25% + 0.10%	34.17	4.09	38.57	3.64	40.20	3.13	40.20	4.89
T_5	Copper oxychloride	0.25%	35.03	1.68	39.17	2.14	41.20	0.72	41.20	2.53
T_6	Mancozeb + Carbendazim + Copper oxychloride	0.25% + 0.10% + 0.25%	33.03	7.29	37.33	6.74	38.20	7.95	39.20	7.26
Bulb dip + Spraying for bulb rot and purple blotch										
T_7	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim)	0.25% + 200 ppm + 0.25% + 0.10%	17.67	50.40	20.13	49.71	21.80	47.46	21.80	48.42
T_8	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Copper oxychloride)	0.25% + 200 ppm + 0.25%	14.00	60.70	17.83	56.30	19.67	52.60	19.67	53.46
T_9	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim + Copper oxychloride)	0.25% + 200 ppm + 0.25% + 0.10% + 0.25%	16.27	54.33	18.97	52.61	20.10	51.56	20.10	52.44
T_{10}	Control	-	35.63	-	40.03	-				

Table 7c: Effect of different chemical treatments on bulb rot incidence of onion under field condition

Tr. No.	Treatment Name	Conc.	At harvesting time	
			Per cent disease incidence	Per cent disease control
Bulb dip for bulb rot				
T_1	Copper oxychloride	0.25%	30.03	28.95
T_2	Streptomycin	200 ppm	24.17	42.81
T_3	Copper oxychloride + Streptomycin	0.25% + 200 ppm	20.77	50.86
Spraying for purple blotch				
T_4	Mancozeb + Carbendazim	0.25% + 0.10%	40.20	4.89
T_5	Copper oxychloride	0.25%	41.20	2.53
T_6	Mancozeb + Carbendazim + Copper oxychloride	0.25% + 0.10% + 0.25%	39.20	7.26
Bulb dip + Spraying for bulb rot and purple blotch				
T_7	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim)	0.25% + 200 ppm + 0.25% + 0.10%	21.80	48.42
T_8	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Copper oxychloride)	0.25% + 200 ppm + 0.25%	19.67	53.46
T_9	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim + Copper oxychloride)	0.25% + 200 ppm + 0.25% + 0.10% + 0.25%	20.10	52.44
T_{10}	Control	-	42.27	-

Effect of different chemical treatments on seed yield of onion

Data on onion seed yield is presented in Table 9 and Fig 2. Result of different chemical treatments on the seed yield onion was found significant over control and was ranged from 432 to 1022 kg/ha as against 317 kg/ha seed yield in control plot. The bulb dip (T9) (copper oxychloride @ 0.25% + streptomycin 200ppm) + spraying with (mancozeb @ 0.25% + carbendazim @ 0.10% + copper oxychloride @ 0.25%) was found significantly superior over rest of the treatment in which the maximum seed yield of onion 1022 kg/ha was obtained and followed by (T7) bulb dip (Copper oxychloride @ 0.25% + streptomycin 200ppm) + spraying with (mancozeb @ 0.25% + carbendazim @ 0.10%) 1003 kg/ha. Different chemical treatments effectively controlled the onion bulb rot incidence and purple blotch with increased seed yield over control in the range of 26.62% to 68.98%.

Table 8: Effect of different chemical treatments on seed yield of onion

Tr. No.	Treatment Name	Conc.	Seed yield gm/plot	Seed yield kg/ ha	Per cent increased seed yield over control
Bulb dip for bulb rot.					
T_1	Copper oxychloride	0.25%	350*	432	26.62
T_2	Streptomycin	200 ppm	455	561	43.49
T_3	Copper oxychloride + Streptomycin	0.25% + 200 ppm	520	641	50.54
Spraying for purple blotch.					
T_4	Mancozeb + Carbendazim	0.25% + 0.10%	445	549	42.25
T_5	Copper oxychloride	0.25%	365	450	29.55
T_6	Mancozeb + Carbendazim + Copper oxychloride	0.25% + 0.10% + 0.25%	463	571	44.48
Bulb dip + Spraying for bulb rot and purple blotch.					
T_7	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim)	0.25% + 200 ppm + 0.25% + 0.10%	813	1003	68.39
T_8	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Copper oxychloride)	0.25% + 200 ppm + 0.25%	745	919	65.50
T_9	Bulb dip (Copper oxychloride + Streptomycin) + Spraying (Mancozeb + Carbendazim + Copper oxychloride)	0.25% + 200 ppm + 0.25% + 0.10% + 0.25%	828	1022	68.98
T_{10}	Control	-	257	317	-

***Mean of three replications.

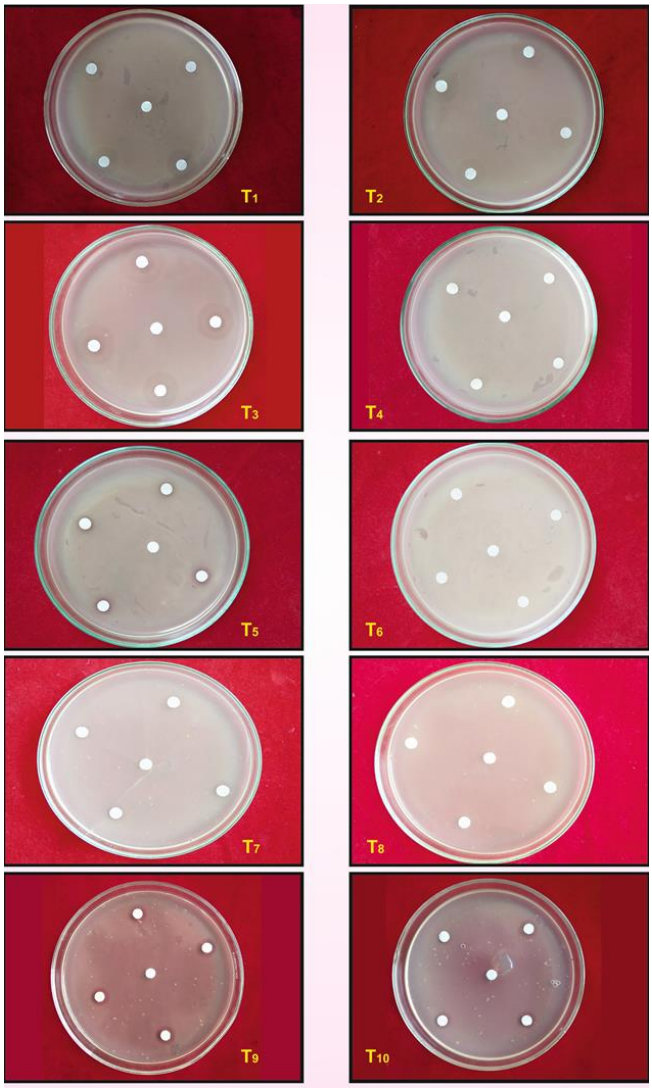

Fig: *In vitro* evaluation of chemicals against the *Erwinia carotovora*

The present investigation was confirmed by the result obtain by Bhagat S. P (2015) [7] reported that maximum seed yield of onion 546 kg/ha against bulb rot of onion. Karim *et al*. (2013) [15] and Ali *et al*. (2015) [3] recorded that seed yield of onion in the ranged of 370 – 500 Kg/ha. Zakirul islam (2013) [31] observed maximum seed yield (649.40 kg/ha) with low incidence and intensity of purple blotch of onion.

Summary

Bulb rot symptoms were noticed at the base of central leaves of onion plant in field condition, longitudinal sections revealed that lesions developed downward and the inner layers of bulb appeared macerated. Infection observed at the inner part of the onion bulb in the neck region, and the decay gradually invades the whole bulb, while the outer scale remains unaffected. In the early stage of bulb infection, the older leaves become severally decayed and all the leaves die.

Pathogenicity test of bacterial pathogen was carried out by bulb and soil inoculation method. The isolate of *Erwinia carotovora* pv. *carotovora* proved to be pathogenic causing bulb rot of onion.

The isolate of *Erwinia carotovora* pv. *carotovora* showed negative reaction towards gram reaction and urease production test where as it shows positive reaction towards KOH test, catalase test, potato soft rot test, gelatin liquification test, growth in 5% Nacl test, H_2S production test, indole production test, oxidase test and methyl red test.

Efficacy of different chemicals were tested by filter paper disc diffusion method against *Erwinia carotovora* pv. *carotovora*. Maximum growth inhibition of test pathogen recorded in copper oxychloride @ 0.25% + streptomycin @ 200 ppm (23.00 mm), followed by streptomycin @ 200 ppm (18.00 mm).

Under field condition, treatment (T8) bulb dip (copper oxychloride @ 0.25% + streptomycin sulphate @ 200 ppm) + spraying with (copper oxychloride @ 0.25%) was found most effective treatment against bulb rot of onion as it recorded minimum disease incidence (19.67%) with maximum disease control (53.46%).

The application of different chemicals significantly influenced seed yield of onion. seed yield was ranged from 432 to 1022 kg/ha as against 317 kg/ha seed yield in control plot. The highest seed yield was recorded in treatment (T9) bulb dip (copper oxychloride @ 0.25% + streptomycin @ 200 ppm) + spraying with (mancozeb @ 0.25% + carbendazim @ 0.1% + copper oxychloride @ 0.25%) i.e 1022 kg/ha as compared to control.

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