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Durgaprasad Yogesh Patil
Department of Plant Pathology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Shashi Tiwari
Department of Plant Pathology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Corresponding Author:
Durgaprasad Yogesh Patil
Department of Plant Pathology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Efficacy of selected chemicals against fruit rot of cucumber [*Cucumis sativus* (L.)] caused by *Fusarium oxysporum* f. sp. *cucumerinum*

Durgaprasad Yogesh Patil and Shashi Tiwari

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Abstract
Cucumber (*Cucumis sativus* L.) is one of the fore most vegetable grown during Zaid season. Fruit rot caused by *Fusarium oxysporum* is one of the emerging disease in all regions wherever cucumber is grown. *Fusarium oxysporum* causes rotting of fruits first in older and mature then to the young fruits during humid temperature. An experiment was conducted to evaluate the efficacy of chemicals viz. T_0 (Untreated control), T_1 (Neem oil @ 5.0%), T_2 (Carbendazim 12% @ 0.3% + Neem oil @ 2.0%), T_3 (Captan 70% @ 0.2% + Neem oil @ 2.0%), T_4 (Fosetyl-Al @ 0.2% + Neem oil @ 2.0%), T_5 (Tebuconazole 50% @ 0.2% + Neem oil @ 2.0%), T_6 (Hexaconazole 5% @ 0.2% + Neem Oil @ 2.0%) against fruit rot of cucumber. Studies revealed that maximum height , maximum no. of leaves , maximum no. of branches and maximum no. of fruits and further minimum disease incidence was observed in T_3 (Captan 70% @ 0.2% + Neem oil @ 2.0%) and the maximum yield and cost benefit ratio was found in T3 (Captan 70% @ 0.2% + Neem oil @ 2.0%). Hereby it is considered as the best treatment.

Keywords: *Cucumis sativus*, Captan, efficacy, *Fusarium oxysporum*, fungicides, Neem oil

1. Introduction
Cucumber (*Cucumis sativus* L.) belongs to the Cucurbitaceae family, which includes around 117 genera and 825 species commonly found in warmer climates (Gopalakrishnan, 2007) [8]. It is grown widely across India, from the plains to high-altitude regions and riverbanks (Munshi *et al.*, 2008) [13]. Originating in India, cucumber exhibits considerable genetic diversity and has been cultivated for over 3, 000 years in regions such as Western Asia and China. From there, it spread to Europe, particularly Greece and Italy. Today, it ranks as the fourth most important vegetable in Asia, following tomato, cabbage, and onion. In India, the cucumber season typically spans from January to April. The fruit is known for its cooling properties and is used to alleviate issues like constipation, jaundice, and indigestion. Cucumber is a low-calorie vegetable with high water content and serves as a vital source of vitamins and minerals for humans (Clarkson *et al.*, 2010) [5].

Global cucumber production was estimated at 93.53 million metric tonnes, a 3.1% increase from the previous figure of 90.75 million tonnes. China dominates global production, contributing about 81% with 75.55 million tonnes (Tatlioglu, 1997) [16]. In India, West Bengal led cucumber production in 2019, accounting for 20.32%, while Uttar Pradesh ranked sixth with 6.45% (Sharma, 2020) [15].

Cucumber seedlings are vulnerable to various soilborne fungal and fungus-like pathogens such as *Pythium*, *Fusarium*, and *Rhizoctonia* species. These pathogens can attack plants before or after emergence, leading to seedling loss, irregular crop stands, and wilting. Infected seedlings develop water-soaked lesions near the soil line, often dying shortly thereafter. Chemical seed treatments remain a common strategy to control damping-off diseases (Babadoost and Islam, 2003) [3].

Fusarium oxysporum is an asexual fungus identified through morphological characteristics like macroconidia shape, microconidiophore structure, and chlamydospore arrangement. Its genome size ranges from 18.1 to 51.5 Mb, contains 7 to 14 chromosomes, and includes linear mitochondrial plasmids (Kistler, 1997) [10]. Transposable elements make up about 5% of its genome. Genetic transformation in *F. oxysporum* has been established for over a decade.

Fusarium wilt thrives in dry conditions with soil temperatures between 20 °C and 30 °C. The fungus survives in infected plant residue, host plants, seeds, or soil. The disease is generally monocyclic, meaning it doesn't spread from plant to plant during the growing season. Instead, it spreads within fields through contaminated soil and between fields via infected tools and plant material. Some forms of *F. oxysporum*, like *f. sp. niveum*, are seed-borne, though contamination levels can vary (Egel and Martyn, 2013) [7].

Fusarium species are highly host-specific and are divided into over 120 special forms and races, each targeting specific host plants or cultivars (Armstrong and Armstrong, 1981) [2]. These soil-dwelling fungi are responsible for several plant diseases, including stem and root rot, vascular wilt, and damping-off (McGovern, 2015) [12]. Fusarium wilt in cucumbers is particularly concerning, and studies have aimed to measure *Fusarium* populations before and after bioorganic fertilizer applications during dry and wet seasons. Biological control methods have shown promising results, and such practices are being promoted in greenhouse cultivation in China. Research has also begun to explore how specific bacterial strains with antifungal properties contribute to this control.

Cucumber root and stem rot is a particularly destructive disease caused by *Fusarium oxysporum f. sp. radices-cucumerinum*. This pathogen caused significant damage in greenhouse cucumber crops in Canada (1994), France (1998), China (1999), and Spain (2000), leading to severe yield losses (Punja & Parker, 2000) [14]. The fungicide carbendazim has shown effectiveness as a soil drench against this disease (Amini and Sidovich, 2010) [1]. However, its repeated use can lead to resistance in the pathogen. Current studies are evaluating the efficacy of various combination fungicides in both laboratory and field settings as part of integrated disease management strategies.

The widespread use of synthetic fungicides has led to resistant pathogen strains (Biles and Martyn, 1989) [4]. Rising chemical costs, environmental contamination, and resistance issues have driven the search for eco-friendly and pathogen-specific biological control methods as more sustainable alternatives.

2. Materials and Methods

2.1 Geographical location and Climate condition of the of the experimental area

The experimental site is situated at 25.41º North latitude and 81.84º East longitude, at an elevation of 98 meters above mean sea level (MSL). Located in Prayagraj, the region falls within a humid subtropical climate zone, characterized by hot, dry summers, warm and humid monsoons, and cold, dry winters. The area experiences an average annual temperature of 26.1 °C, with monthly averages ranging from 18 °C to 29 °C. Daily average high and low temperatures are approximately 22 °C and 9 °C, respectively. Annual rainfall averages around 1042.2 mm. Extreme temperatures at this site can climb as high as 46 °C to 48 °C, while the lowest recorded temperatures range from 4 °C to 5 °C. Relative humidity levels fluctuate between 20% and 94%.

2.2 Experiment details

The in-vivo experiment took place in the experimental field at the Department of Plant Pathology, Central Research Farm, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj.

2.3 Seed rate and sowing

The seeds of the cucumber variety Super Green were used for sowing. Sowing was done by dibbling one seed at each hill in a row at a depth 4-5 cm by maintaining a 30 cm inter-row and 10 cm intra row distance with the seed rate of 2.5 Kg/ha.

Table 1: Experiment Details

T. No	Treatments
T_0	Control
T_1	Neem oil @ 5.0%
T_2	Carbendazim 12% @ 0.3% Neem oil @ 2.0%
T_3	Captan 70% @ 0.2% Neem oil @ 2.0%
T_4	Fosetyl-Al @ 0.2% + Neem oil @ 2.0%
T_5	Tebuconazole 50% @ 0.2% + Neem oil @ 2.0%
T_6	Hexaconazole 5% @ 0.2% + Neem Oil @ 2.0

3. Results and Discussions

The results reveals the response of different chemicals on plant height of cucumber at 90 DAS under field conditions. Among all the treat ments the maximum plant height was recorded in T_3 (Captan 70% + Neem oil, 171.0) follow ed by T_4 (Fosetyl-Al + Neem oil, 158.06), T_5 (Tebuconazole 50% + Neem oil, 137.73), T_6 (Hexaconazole 5% + Neem Oil, 128.73), T_2 (Carbendazim 12% + Neem oil, 127.80), T_1 (Nee m oil, 126.33), and T_0 (Control, 96.0). All the treatments were statistically significant over T_0 control.

In the present study plant height at 30, 60 and 90 DAS was recorded in Captan + neem oil followed by Fosetyl + neem oil and was found to be effective over other treatments. This result was similar to the findings of Uraiha *et al.* (2020) [7] in that the height was found maximum in carbendazim + mancozeb.

The effect of different chemicals on the number of leaves of cucumber after 90 DAS under field conditions. Among all the treatments the maximum number of leave s were recorded in T_3 (Captan 70% + Neem oil, 47.73) followed by T_4 (Fosetyl Al + Neem oil, 43.13), T_5 (Tebuconazole 50% + Neem oil, 41.13), T_6 (Hexaconazole 5% + Neem Oil, 41.0), T_1 (Neem oil, 40.33), T_2 (Carbendazim 12% + Neem oil, 39.26), and T_0 (Control, 26.13). All the treatments were statistically significant and over T_0 control. In the present study number of leaves at 30, 60 and 90 DAS was recorded in Captan + neem oil followed by Fosetyl + neem oil was found to be effective over other treatments. This result was similar to the findings of Kengar *et al.* (2017) [9] in which the number of leaves was found maximum in the foliar spray of Hexaconazole.

The effect of different chemicals on the number of branches of cucumber at 90 DAS under field conditions. Among all the treatments the maximum number of branches were recorded in T_3 (Captan 70% + Nee m oil, 6.00) followed by T_4 (Fosetyl Al + Neem oil, 5.00), T_5 (Tebuconazole 50% + Neem oil, 4.66), T_1 (Neem oil, 3.93), T_2 (Carbendazim 12% + Neem oil, 3.86), T_6 (Hexaconazole 5% + Neem Oil, 3.66), and T_0 (Control, 3.00). Comparing the treatments with CD value (0.75). All the treatments were statistically significant over the T_0 control whereas (T_6, T_7), (T_6, T_2, T_1), and (T_2, T_5) are statically at par with each other. In the present study the maximum number of branches at 30, 60 and 90 DAS was recorded in Captan + neem oil followed by Fosetyl + neem oil and was found to be effective over other treatments. This result was similar to the findings of Uraiha *et al.* (2020) [7] in that the number of branches was found maximum in Tebuconazole + neem oil.

The results revealed the response of different chemicals on the number of cucumber fruits at 120 DAS under field conditions. Among all th e treatments the maximum number of fruits were recorded in by T_3 (Captan 70% + Neem oil, 12.66) T_4 (Fosetyl Al + Neem oil, 12.46), followed T_6 (Hexaconazole 5% + Neem Oil, 10.46, T_5 (Tebuconazole 50% + Neem oil, 10.20), T_2 (Carbendazim 12% + Neem oil, 10.0), T_1 (Ne em oil, 9.46), and T_0 (Control, 6.66). Comparing the treatments with CD value (0.84). All the treatments were statistically significant over the T_0 control whereas (T_1, T_2, T_5), (T_2, T_5, T_6) and (T_4, T_3) are statically at par with each other.

The studies revealed that all the treatments were significantly superior to the untreated (control) T_0 in reducing the disease incidence at 120 DAS. The minimum percent disease incidence (%) was recorded in T_3 (Captan 70% + Neem oil, 36.34%) which was further follo wed by T_4 (FosetylAl + Neem oil, 38.56%), T_5 (Tebuconazole 50% + Neem oil, 43.19%), T_6 (Hexaconazole 5% + Neem Oil, 45.69%), T_2 (Carbendazim 12% + Neem oil, 45.98%), and T_1 (Neem oil, 47.18), and maximum incidence was recorded in T_0 (Control, 47.81%). All the treatments were found statically significant but (T_3, T_4) and (T_6, T_2, T_1, T_0) were at par with each other.

In the present study, the minimum incidence at 60, 90 and 120 DAS was recorded in Captan + neem oil followed by Fosetyl + neem oil and was found to be effective over other treatments. This result was similar to the findings of Koohakan *et al.* (2020) [11]. In this studies, minimum incidence was found with seed coating with captan (38%).

Data presented showed that, among all treatments, maximum yield (q/ha) was recorded in Treatment T_3 (Captan 70% @ 0.2% Neem oil @ 2.0%) i.e. 110.30 q/ha which was superior over all treatments followed by T_4 (Fosetyl-Al @ 0.2% + Neem oil @ 2.0%) 105.55, T_5(Tebuconazole 50% @ 0.2% + Neem oil @ 2.0%) 103.10, T_2 (Carbendazim 12% @ 0.3% Neem oil @ 2.0%)83.76, T_1 (Neem oil @ 5.0%) 78.20, T_6 (Hexaconazole 5% @ 0.2% + Neem Oil @ 2.0) 64.80 as compared to control (45.10).

Table 1: Effect of treatments on the Plant Height (cm), Number of Leaves, number branches and Number of fruits per plant of cucumber at different time intervals.

s	Treatments	Plant height (cm)	Number of leaves	Number of branches	Number of fruit per plant
T_0	Control	96	26.1	3	6.6
T_1	Neem oil @ 5.0%	126.3	40.3	3.9	9.47
T_2	Carbendazim 12% @ 0.3% Neem oil @ 2.0%	127.8	39.2	3.8	10
T_3	Captan 70% @ 0.2% Neem oil @ 2.0%	171.2	47.7	6	12.6
T_4	Fosetyl-Al @ 0.2% + Neem oil @ 2.0%	158.3	43.1	5	12.4
T_5	Tebuconazole 50% @ 0.2% + Neem oil @ 2.0%	137.9	41.13	4.6	10.2
T_6	Hexaconazole 5% @ 0.2% + Neem Oil @ 2.0	128.9	41	3.6	8.8
	C.D. (5%)	12.08	3.36	0.35	0.84
	S. Ed (±)	5.56	7.15	0.35	0.39

Table 2: Effect of treatments on the Disease Incidence and Fruit Yield (q/ha) of cucumber at different time intervals.

Tr. No	Treatments	Disease Incidence			Fruit Yield (q/ha)
		60 DAS	90 DAS	120 DAS	
T_0	Control	44.4	46.85	47.81	45.1
T_1	Neem oil @ 5.0%	42.3	46.75	47.18	78.2
T_2	Carbendazim 12% @ 0.3% Neem oil @ 2.0%	42.12	45.31	45.98	83.76
T_3	Captan 70% @ 0.2% Neem oil @ 2.0%	32.74	31.85	36.34	110.3
T_4	Fosetyl-Al @ 0.2% + Neem oil @ 2.0%	32.96	34.49	38.56	105.55
T_5	Tebuconazole 50% @ 0.2% + Neem oil @ 2.0%	37.27	43.14	43.19	103.1
T_6	Hexaconazole 5% @ 0.2% + Neem Oil @ 2.0	41.12	45.04	45.69	64.8
	C.D. (5%)	2.45	2.06	2.37	2.56
	S. Ed (±)	1.43	0.98	1.09	1.48

4. Conclusion

From the present study entitled "Efficacy of selected chemicals against fruit rot of cucumber (*Cucumis sativus*) caused by *Fusarium oxysporum* f. sp. *cucumerinum*" it was concluded that Captan + Neem oil was found most efficient against Fruit rot (*Fusarium oxysporum*) of cucumber at affected Cucumber. Consequently it can be suggest for the better treatment of fruit rot of cucumber after Fosetyl-Al + Neem oil.

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