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## RESEARCH ARTICLE

# DOES THE EFFICACY OF A FUNGICIDE VARIES WITH COMPANY BRAND NAME AND ITS IMPLICATION ON PLANT DISEASE CONTROL

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**ABSTRACT**

Fungicides are major inputs in management of plant diseases in cultivated crop plants. Various pesticide companies manufacture the same technical fungicide with different brand name. However, the same technical fungicide of different companies has same efficacy on a particular plant pathogen/disease or otherwise, is not yet investigated. The aim of the present investigation, was to assess the variation in efficacy of seed protectant fungicides viz. Carbendazim, Captan, Metalaxyl+Mancozeb and Copper oxychloride of different companies in *in vitro* against chickpea (Cicer arietinum L.) wilt pathogen Fusarium oxysporum f.sp.ciceri *(Padwick)Matuo & Sato*, on elimination of seed borne microflora on chickpea seed and in *in vivo* against chickpea wilt disease. Under *in vitro test*, the fungicide carbendazim of Dhanuka, Zuari and BASF company was equally effective at various concentrations. The fungicide Metalxyl + Mancobez of UPL, Syngenta and Indofil at 0.05% concentration varied in its efficacy against the fungal pathogen. The fungicide Copper oxychloride of Indofil was most effective at 0 .1 %, followed by Rallis at 0.15 % while it was ineffective even at 0.2 % concentration for Zuari company. As a seed dresser fungicide, Metalxyl + Mancozeb of Syngenta, Indofil and UPL company at 1 % concentration eliminated the seed borne microflora on 100 %, 68.75 % and 43.75 % Cicer arietinum L. seeds respectively. The fungicide Carbendazim of Dhanuka, Zuari and BASF at 2 % concentration was equally effective as seed dresser. However, at 1 % concentration the fungicide carbendazim of Dhanuka company was more effective than that of other two companies. The fungicide Captan of Zuari and Rallis company was more effective than that of Indofil and Makthesian company at 2% concentration and thus varied in its efficacy as seed dresser among these companies. Under in vivo test, the results obtained for the control of chickpea wilt were similar to seed dresser fungicide Carbendazim and Captan, but the fungicide Metalxyl + Mancozeb was not at all effective as seed treatment to control the wilt disease. In conclusion, there was variation in the efficacy of the same fungicide of different companies in the inhibition of fungal growth of *Fusarium oxysporum f.sp. ciceri (Padwick)Matuo & Sato*,and the wilt disease caused by it. Therefore, the answer to the question does the efficacy of a fungicide varies with company brand name is in affirmation and have its implication on plant disease control.



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## INTRODUCTION

Seed is the basic input for growing food and vegetable crops for sustenance of human life on this earth. This seed is also a source of existence and survival of various saprophytic and plant pathogens on it. Seed borne and soil borne diseases causes huge losses of different intensities on various crops around the world (Cramer, 1967., Neergaard, 1977). This seed borne infection can be eliminated with seed treatment by seed protectant fungicides which not only eliminates the seed borne microflora but also protect the emerging seedlings form the infection of soil borne plant pathogens (Cortivo *et al*., 2017).

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Among the seed protectant fungicides Carbendazim, followed by Captan, Metalaxyl+Mancozeb and Thirum are widely used (Griffith and Matthews, 1969, Mondal, 2004., Charanjit Kaur *et al*., 2007). Different factors like soil type, presence of organic matter in soil affect the efficacy of seed protectant fungicides (Sartori *et al*., 2020). However, it is not yet studied whether the same seed protectant fungicide produced by different manufacturing companies varies in its fungicidal efficacy. Therefore, in the present study, 4 seed protectant fungicide viz. Carbendazim, Captan, Copper oxychloride and Metalaxyl + Mancozeb individually produced by 3 to 4 different manufacturing companies were studied, for their comparative efficacy under *in vitro* and *in vivo* tests against the chickpea (Cicer arietinum L.) wilt pathogen fusarium oxysporium f.sp. ciceri *(Padwick)Matuo*

*& Sato,* and also on the seed borne microflora of chickpea seed as seed dressing fungicides. These results will be very much useful to ascertain that the crop cultivators should prefer the seed protectant fungicide of which company to derive the maximum benefit from its use.

## MATERIAL AND METHODS

**Test Fungicides used in the experimentation with company brand name:** The fungicides used in the *in vitro* and *in vivo* experimentation to study their efficacy as seed dresser and root protectant are listed in the Table 1 with the name of manufacturing company. A single fungicide of at least 3 to 4 companies was evaluated for comparison of their efficacy in poison food technique, as seed dresser on seed borne microflora of Cicer arietinum L. seed and as root protectant from wilt pathogen *Fusarium oxysporum f.sp. ciceri (Padwick)Matuo & Sato,* in *fusarium* affected soil.

**Test Pathogen used in the experimentation**

**Wilt Pathogen *Fusarium oxysporum f.sp. ciceri*** *(Padwick) Matuo& Sato*

**Isolation of wilt pathogen from wilted** Cicer arietinum L. **plant:** Roots of wilted Cicer arietinum L. plants showing typical disease symptoms were collected for isolation of the wilt causing pathogen. The collected samples were washed under tap water to remove soil particles and dried. Isolation of the pathogen was done by tissue isolation method on Potato- dextrose -Agar (PDA) medium. The root sample was cut in to suitable pieces, disinfected with 0.1%mercuric chloride solution for 1 minute followed by rinsing in three changes of sterilized water to remove the traces of mercuric chloride solution and were dried on sterilized blotter paper. Three to four such pieces were then placed aseptically on sterilized PDA medium in each petri plates. The petri plates were incubated in BOD incubator at 27$^{o}$C temperature for 3 days. The fungal growth radiating from the isolation sample were picked up and transferred to another PDA plates to obtain the pure culture of the wilt pathogen *Fusarium.* The fungal culture was observed microscopically for the presence of spores of *Fusarium* and upon confirmation the culture from the growth plate was transferred on PDA slants for their preservation.

**Confirmation of Pathogenicity of wilt pathogen on** Cicer arietinum L. **seedlings:** Pathogenicity test of isolated fungal wilt pathogen was done on Cicer arietinum L.seedlings grown in plastic pots. For this, the fungal pathogen was multiplied on PDA media in petri plates for ten days and then uniformly mixed with sterilized soil containing FYM (1:1 ratio). This soil containing wilt pathogen was filled in medium sized plastic pots. The soil without fungal pathogen served as control. 10 seeds of Cicer arietinum L.were dibbled in each *fusarium* soil pot and control pots. The pots were watered as and when required and wilting of chickpea seedling was recorded after 20 days. The re-isolation of the pathogen was done for the confirmation for the *fusarium* fungus in wilted plant samples.

**Preparation of wilt pathogenic sick soil for pot culture experimentation:** For preparation of wilt sick soil, the mass fungal culture of wilt pathogen was prepared on overnight water-soaked sorghum grains, sterilized in bottle. A fungal culture was inoculated in sterilized crushed sorghum grains in bottles and incubated in BOD incubator at 28$^{o}$C for 10 days for the growth of *fusarium* fungus with sporulation. A culture from 20 bottles were mixed with 50 Kg of sterilized Soil-FYM mixture and incubated at room temperature for 15 more days for the growth of fungus to make the soil *fusarium* sick. This soil was used in the pot experimentation to assess the efficacy of different fungicides of various companies on the control of Cicer arietinum L. wilt.

***In Vitro* evaluation of Fungicides for its efficacy against the wilt pathogen:** All the systemic and non-systemic test fungicides were evaluated under *in vitro* studies for their efficacy on mycelial growth of *Fusarium oxysporum f. sp. ciceri (Padwick)Matuo & Sato* by employing poisoned food technique (Nene and Thapliyal,1993). Fungicides of the same technical name but manufactured by different companies were tested against the pathogen at concentration of 0.025, 0.05, 0.1, 0.15 and 0.2 % respectively. The Seed treatment fungicides viz. Carbendazim, Metalaxyl + Mancozeb and Copper oxychloride were evaluated for their efficacy on mycelial growth of *Fusarium oxysporium f.sp.ciceri (Padwick)Matuo & Sato*. Different concentrations of the fungicides as mentioned above was prepared by adding appropriate amount of fungicides in sterilized lukewarm PDA medium and poured in sterilized glass petri plates @ 20mL per plate. PDA without fungicide served as control. A fungal disc of 5 mm of test pathogen was cut from the mother culture plate with sterilized cork- borer and was placed in the centre of each plate amended with the respective fungicides. The testing for each concentration was carried out in five replications to derive the average growth. The plates were incubated in BOD incubator for 3 days at a temperature of 27 ± 1$^{o}$C. Inoculated PDA plates without fungicide served as control. The percent inhibition of mycelial growth over control was recorded (in cm) after 3 rd and 10th days of incubations by formulae given by Nikam *et al*., (2007).

$$\text{Percent Inhibition (I)} = \frac{\text{C-T x 100}}{\text{C}}$$

Where,

C = Growth of test fungus (in cm) in control plate
T= Growth of test fungus (in cm) in fungicide amended plates.

Data of colony diameter and percentage of inhibition were analysed statistically to observe the difference among the various fungicide treatment.

***In Vitro* evaluation of Fungicide for its efficacy as Seed Dresser on Cicer arietinum L. seed microflora:** The fungicide Carbendazim, Metalxyl + Mancozeb and Captan were evaluated as seed dresser under *in vitro* condition against the seed borne infection of chickpea. The seeds were moistened with sterile water so as to get the fungicide adhere to the seeds. The moistened seeds were dressed with respective fungicide of different companies individually at 0.5, 1.0. and 2.0 % concentration and were kept on sterile water soaked germination paper. Seeds without fungicide treatment served as control. The germination paper having seeds were folded and incubated at 27 ± 1$^{0}$C temperature in germination incubator. After a week the seeds were observed for the presence of seed microflora on chickpea seed particularly for *Alternaria, Aspergillus, Ascochyta,*

*Cheatomium, Bipolaris, Curvularia, Botrytis, Rhizopus, Colletotrichum* and *Fusarium* (Hossain *et al*., 2017) under stereo binocular microscope and control of seed microflora on percentage seed was calculated.

***In vivo* evaluation of Fungicides for its efficacy in control of Cicer arietinum L. wilt disease:** The test fungicides found to be the most effective in inhibiting the mycelial growth of the wilt pathogen under *in vitro* were further evaluated for their efficacy in glass house experimentation for the control of Cicer arietinum L.wilt. The Cicer arietinum L.seeds were treated with test fungicides Carbendazim, Metalxyl + Mancozeb and Captan of different companies @ 0.5, 1.0 and 2.0% concentration individually (dry seed treatment) and sown in pot soil (@ 10 seeds/pot) having Fusarium sick soil as mentioned in pathogenicity test. The untreated seeds sown in the fusarial soil pots served as a control. Two pots for each treatment was used. The pots were watered when needed. The wilt disease incidence in test fungicides were recorded when wilt symptoms started appearing in the control experimental pots and the second reading was taken 5 days after the 1st reading. The data were recorded on percent infected (wilted) plants and percent inhibition of wilting by fungicidal seed treatment was calculated as under

$$\% \text{ Wilt reduction} = \frac{\text{Seedling wilted in control} \quad \text{Seedling wilted in fungicidal treatment}}{\text{Seedling wilted in control}} \times 100$$

**Statistical analysis:** On the basis of observation recorded on different parameters, the statistical analysis was done from the department of agricultural statistics of Mahatma Phule Agriculture University, Rahuri, Maharashtra state. To compare two treatment means, critical differences (CD) at 5% level of significance was worked out.

## RESULT AND DISCUSSION

***In vitro* evaluation of various Seed protectant fungicides of different companies against *Fusarium oxysporum f.sp. ciceri (Padwick) Matuo & Sato* by poison food technique.**

**Evaluation of Seed protectant fungicide Carbendazim, Metalaxyl + Mancozeb and Copper oxychloride of different companies on Cicer arietinum L. wilt pathogen:** The fungicide carbendazim of 3 companies viz. Dhanuka, Zuari and BASF, the fungicide Metalxyl + Mancozeb of 3 companies viz. Syngenta, UPL and Indofil and the fungicide Copper oxychloride of 3 companies viz. Zuari, Rallis and Indofil individually at 0.025, 0.05, 0.1, 0.15 and 0.2 % concentrations were evaluated against the Cicer arietinum L wilt pathogen *Fusarium oxysporum f. sp.ciceri (Padwick) Matuo & Sato* as test pathogen under *in vitro* test by poison food technique . The PDA media amended with the respective concentration of the particular fungicide of all the companies were tested for its efficacy against the test pathogen. PDA media without fungicide served as control. The percent inhibition of fungal colony growth (IFC) were calculated on the basis of mycelial growth (in cm) obtained in fungicide amended media and on plain media. The results are summarized in Table 2, 3 and 4. The results (Table 2) indicate that all the concentrations of carbendazim of all the three companies were effective against the Cicer arietinum L. wilt fungus *F. o. f. sp. Ciceri (Padwick) Matuo & Sato*. There was 100% inhibition of fungal growth by this fungicide of all the 3 companies. Thus there was no variation in the efficacy of Carbendazim of different companies. The result (table3) indicate that Metalxyl + Mancobez of UPL was most effective than that of Syngenta and Indofil. At fungicide concentation of 0.05 %, the growth of *Fusarium* colony in Metalaxyl + Mancozeb poisoned plate of UPL was 5 cm, whereas it was 8 cm for Syngenta and 7.5 cm for Indofil as against 9 cm in control plate. Thus, at this concentration of 0.05%, the percent inhibition of fungal colony by this fungicide of UPL company was 44.45 % as against 11.12 % of Syngenta and 16.67 % of Indofil company. The results of fungicide concentration as well as the fungicide company were statistically significant. These results indicate that the efficacy of Meatlaxyl + Mancozeb varies with the company brand at the same fungicidal concentration. The results (Table 4) indicate that 0.1 % concentration of Copper oxychloride of Indofil was most effective as it had 100 % inhibition of fungal colony. At this concentration the fungicide of Zuari and Rallis had 8.5 cm growth of fungal colony as against 9 cm in control plate. The fungicide of Rallis was effective at 0.15 % concentration and had 100 % inhibition of fungal colony at this concentration. The same fungicide of Zuari even at 0.2 % concentration was not effective and produced the mycelial growth of 8.5 cm as against 9 cm in control plate. Though, the results for Copper oxychloride concentration and company were not significant it was evident from the Table that the Copper oxychloride of Indofil company was more effective than that of Zuari and Rallis company (Fig.1). It is evident from these results that among the fungicides Carbendazim, Metalxyl+ Mancozeb, and Copper oxychloride tested against the Cicer arietinum L wilt pathogen *F.o.f.sp. ciceri(Padwick)Matuo & Sato*, the fungicide Carbendazim followed by Copper oxychloride was most effective. The fungicide Carbendazim was effective at 0.025 % concentration whereas the fungicide Copper oxychloride was effective at 0.1 % concentration. Further the fungicide Copper oxychloride of Indofil was more effective than the fungicide of Zuari and Rallis company. The fungicide Carbendazim of all the three companies viz. Dhanuka, Zuari and BASF was equally effective against the chickpea wilt pathogen.

***In vitro* evaluation of various fungicides of different companies as Seed dresser against Seed borne pathogens of Cicer arietinum L**

**Evaluation of Metalxyl + Mancozeb, Carbendazim and Captan as seed dresser on the seed microflora of Cicer arietinum L:** The fungicide Metalxyl + Mancozeb of 3 companies viz. Syngenta, UPL and Indofil, the fungicide Carbendazim of 3 companies viz. Dhanuka, Zuari and BASF and the fungicide Captan of 4 companies viz. Zuari, Makthesian, Indofil and Rallis individually at 0.5, 1.0 and 2.0 % concentrations were evaluated as seed dresser for control of seed borne infection on Cicer arietinum L seeds. The fungicide treated seeds of particular concentration were observed under stereo- binocular microscope for the presence of the seed borne microflora. The results on the efficacy of these fungicides at particular concentrations are presented in Table 5, 6 and 7. The results (Table 5) indicate that the fungicide Metalxyl + Mancozeb of Syngenta company at 1 % concentration was most effective as it had controlled the seed borne pathogen on 100 % seeds of Cicer arietinum L.

**Table1. Fungicides of the companies used in the experimentation**

| Name of Fungicide | Name of Company | | | |
|---|---|---|---|---|
| Captan | Indofil chemicals | Rallis | Zuari Industries Ltd | Makthesian Agan India |
| Carbendazim | DhanukaAgritech limited | BASF | Zuari Industries Ltd | |
| Copper oxychloride | Indofil chemicals | Rallis | Zuari Industries Ltd | |
| Metalxyl + Mancozeb | Indofil Industries | Syngenta | United Phosphorus Ltd | |

**Table 2. *In vitro* fungicidal effect of carbendazim of various companies on growth of wilt pathogen *Fusarium oxysporum. f.sp.ciceri of chickpea***

| Fungicide conc. (%) | Fungal colony growth of *Fusarium oxysporum.f.sp.ciceri* (in Cm) in fungicide carbendazim amended media of different companies | | | | | |
|---|---|---|---|---|---|---|
| | Dhanuka | % IFC[a] | Zuari | % IFC[a] | BASF | % IFC[a] |
| 0.025 | 0.0 | 100 | 0.0 | 100 | 0.0 | 100 |
| 0.05 | 0.0 | 100 | 0.0 | 100 | 0.0 | 100 |
| 0.1 | 0.0 | 100 | 0.0 | 100 | 0.0 | 100 |
| 0.15 | 0.0 | 100 | 0.0 | 100 | 0.0 | 100 |
| 0.2 | 0.0 | 100 | 0.0 | 100 | 0.0 | 100 |
| 0.0(control) | 9 | | | | | |

*a. % inhibition of mycelial colony.*

**Table 3. *In vitro* fungicidal effect of Metalaxyl + Mancozeb of various companies against a wilt pathogen *Fusarium oxysporum f.sp.ciceri* of chickpea**

| Fungicide conc. (%) | Fungal colony growth of *Fusarium* oxysporum f.sp.ciceri (in Cm) in fungicide Metalaxyl + Mancozeb amended media of different companies | | | | | |
|---|---|---|---|---|---|---|
| | Syngenta | % IFC[a] | UPL | % IFC[a] | Indofil | % IFC[a] |
| 0.025 | 8.0 | 11.12 | 6.0 | 33.34 | 7.5 | 16.67 |
| 0.05 | 8.0 | 11.12 | 5.0 | 44.45 | 7.5 | 16.67 |
| 0.1 | 7.0 | 22.23 | 5.0 | 44.45 | 7.0 | 22.23 |
| 0.15 | 7.0 | 22.23 | 5.0 | 44.45 | 6.0 | 33.34 |
| 0.2 | 7.0 | 22.23 | 5.0 | 44.45 | 5.0 | 44.45 |
| 0.0(control) | 9 | | | | | |

| | SE(m)[b] | CD[c] | CV[d] |
|---|---|---|---|
| Concentration | 0.380058 | 1.197589 | 9.633374 |
| Company | 0.268742 | 0.846823 | |

*a= % inhibition of mycelial colony, b =standard error, c= critical difference, d=coefficient of variation..*

**Table 4. *In vitro* fungicidal efficacy of Copper oxychloride of various companies against a wilt pathogen *Fusarium oxysporum f.sp.ciceri* of chickpea**

| Fungicide conc. (%) | Fungal colony growth of *Fusarium oxysporium f.sp.cicer i*(in Cm) in fungicide Copper oxychloride amended media of different companies | | | | | |
|---|---|---|---|---|---|---|
| | Zuari | % IFC[a] | Rallis | % IFC[a] | Indofil | % IFC[a] |
| 0.025 | 8.5 | 5.56 | 8.5 | 5.56 | 8.5 | 5.56 |
| 0.05 | 8.5 | 5.56 | 8.5 | 5.56 | 8.5 | 5.56 |
| 0.1 | 8.5 | 5.56 | 8.5 | 5.56 | 0.0 | 100 |
| 0.15 | 8.5 | 5.56 | 0.0 | 100 | 0.0 | 100 |
| 0.2 | 8.5 | 5.56 | 0.0 | 100 | 0.0 | 100 |
| 0.0(control) | 9 | | | | | |

| | SE(m)[b] | CD[c] | CV[d] |
|---|---|---|---|
| Concentration | 1.715669 | NS[e] | 47.75826 |
| Company | 1.213161 | NS[e] | |

*a= % inhibition of mycelial colony, b=standard error,c= critical difference, d=coefficient of variation, e=non-significant*

**Table 5. *In vitro* fungicidal efficacy of Meatlxyl + Mancozeb of various companies as seed dresser treatment against seed borne pathogens on chickpea seed**

| Fungicide conc. (%) | Number of seeds with externally seed borne microflora after seed treatment with fungicide Metalxyl + Mancozeb of different companies | | | | | |
|---|---|---|---|---|---|---|
| | Syngenta | % control of infected seeds | UPL | % control of infected seeds | Indofil | % control of infected seeds |
| 0.5 | 28 | 12.5 | 22 | 31.25 | 10 | 68.75 |
| 1.0 | 0 | 100 | 18 | 43.75 | 10 | 68.75 |
| 2.0 | 0. | 100 | 18 | 43.75 | 10 | 68.75 |
| 0.0(control) | 32 | | | | | |

**Table 6. *In vitro* fungicidal efficacy of Carbendazim of various companies as seed dresser treatment against seed borne pathogen on chickpea seeds**

| Fungicide conc. (%) | Number of seeds with externally seed borne microflora after seed treatment with fungicide Carbendazim of different companies | | | | | |
|---|---|---|---|---|---|---|
| | Dhanuka | % control of infected seeds | Zuari | % control of infected seeds | BASF | % control of infected seeds |
| 0.5 | 8 | 75 | 8 | 75 | 10 | 68.75 |
| 1.0 | 0 | 100 | 8 | 75 | 10 | 68.75 |
| 2.0 | 0 | 100 | 0 | 100 | 0 | 100 |
| 0.0(control) | 32 | | | | | |

**Table 8. *In vivo* fungicidal efficacy of Carbendazim as seed treatment for control of chickpea wilt disease**

| Fungicide conc. (%) | Percent wilted chickpea plants after Carbendazim seed treatment of different companies | | | | | |
|---|---|---|---|---|---|---|
| | Dhanuka | % control of wilting | Zuari | % control of wilting | BASF | % control of wilting |
| 0.5 | 32 | 75 | 100 | 0 | 100 | 0 |
| 1.0 | 0 | 100 | 100 | 0 | 100 | 0 |
| 2.0 | 0 | 100 | 0 | 100 | 0 | 100 |
| 0.0(control) | 100 | | | | | |

**Table.9. *In vivo* fungicidal efficacy of Fungicide Captan of various companies as seed treatment for the control of chickpea wilt disease**

| Fungicide conc. (%) | Percent wilted plants after seed treatment with Captan of different companies | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Zuari | % control of wilting | Makthesian | % control of wilting | Indofil | % control of wilting | Rallis | % control of wilting |
| 0.5 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 |
| 1.0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 |
| 2.0 | 33.34 | 66.66 | 100 | 0 | 100 | 0 | 100 | 0 |
| 0.0(control) | 100 | | | | | | | |

**Table 10. *In vivo* fungicidal efficacy of Metalxyl + Mancozeb as seed treatment for control of chickpea wilt disease**

| Fungicide conc. (%) | Percent wilted chickpea plants after Metalxyl + Mancozeb seed treatment of different companies | | | | | |
|---|---|---|---|---|---|---|
| | Syngenta | % control of wilting | UPL | % control of wilting | Indo fill | % control of wilting |
| 0.5 | 100 | 0 | 100 | 0 | 100 | 0 |
| 1.0 | 100 | 0 | 100 | 0 | 100 | 0 |
| 2.0 | 100 | 0 | 100 | 0 | 100 | 0 |
| 0.0(control) | 100 | | | | | |

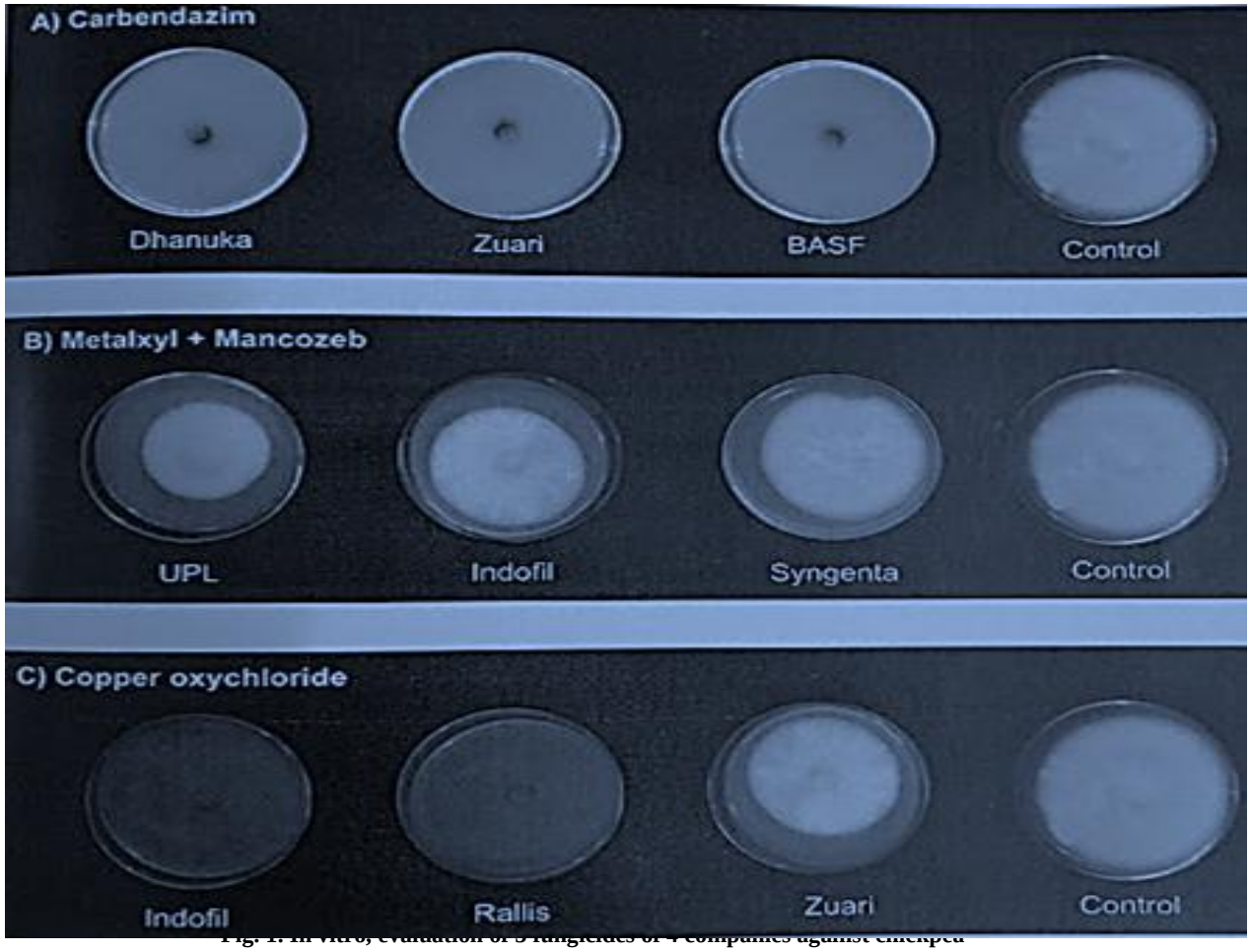


**Fig. 1. In vitro, evaluation of 3 fungicides of 4 companies against chickpea wilt pathogen *Fusarium oxysporum f.sp.ciceri.***

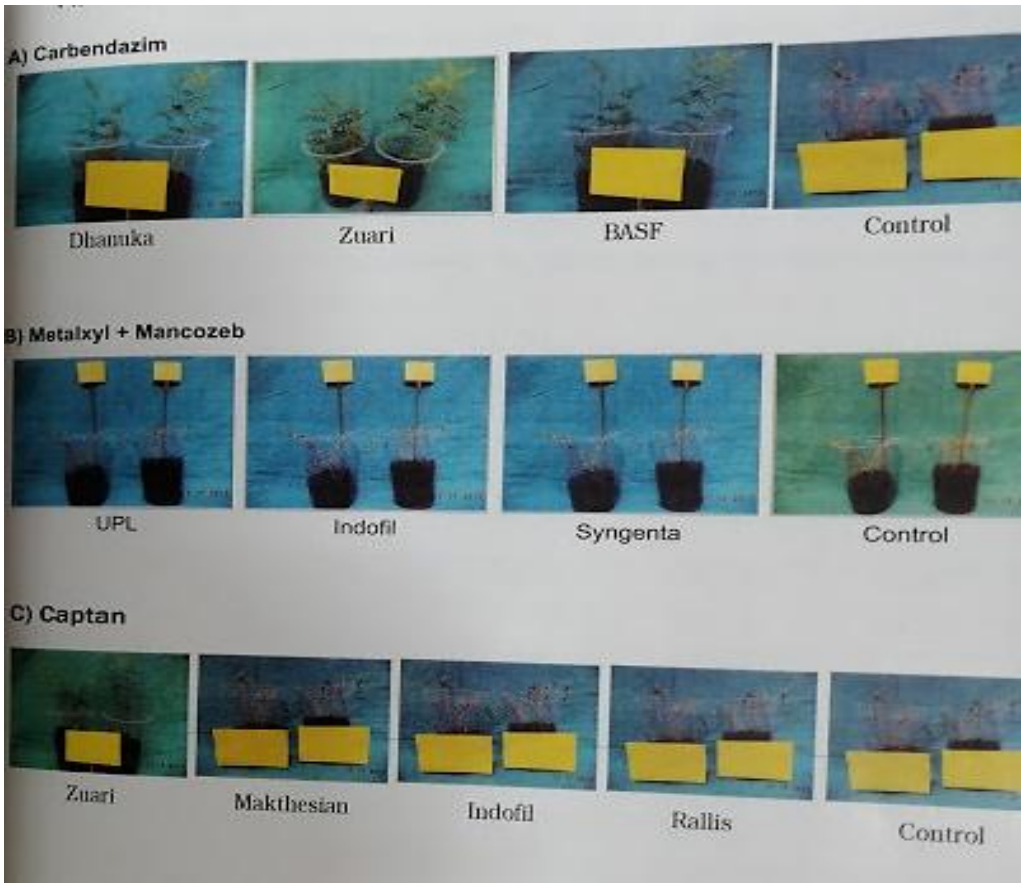


**Fig.2. In vivo evaluation of fungicides of different companies as seed dresser for control of chickpea wilt**

The same fungicide of other companies particularly Indofil controlled the seed borne infection on 68.75 % seeds while that of UPL company controlled seed borne infection on 43.75 % seeds. Thus the fungicide Metalxyl + Mancozeb of Syngenta company was more effective than the same fungicide from other companies as seed dresser. The results (Table 6) indicate that the fungicide Carbendazim of all the companies at 2 % concentration was equally effective i.e. it controlled the seed borne infection on 100 percent seeds and thus the seeds were free from seed borne infection. However, at 1 % concentration the fungicide of Dhanuka company was more effective than the fungicide of other two companies. The results (Table 7) indicate that the fungicide Captan of Zuari and Rallis company was more effective in checking the seed borne infection on chickpea seeds and at 2 % concentration it had controlled the seed borne infection on 100 percent seeds as compare with the same fungicide of other two companies. These results clearly indicate that for seed treatment of Cicer arietinum L seeds to control seed borne pathogens, Carbendazim at 2 % concentration of all the 3 companies was most effective, while Metalxyl + Mancozeb of Syngenta company and Captan of Zuari and Rallis company was effective at the same fungicidal concentration.

***In vivo* evaluation of various fungicides of different companies against Cicer arietinum L wilt disease**

**Evaluation of Carbendazim, Captan and Metalaxyl + Mancozeb:** The fungicide Carbendazim of 3 companies viz. Dhanuka, Zuari and BASF, the fungicide Captan of 4 companies viz. Zuari, Makthesian, Indofil and Rallis and the fungicide Metalxyl + Mancozeb of 3 companies viz. Syngenta, UPL and Indofil individually at 0.5, 1.0 and 2.0 % concentrations were evaluated as seed treatment for the control of wilt disease of Cicer arietinum L. The results of fungicidal efficacy as seed treatment in control of chickpea wilt are presented in Table 8,9 and 10. The results (table.8) indicate that the fungicide Carbendazim of all the three companies viz. Dhanuka, Zuari and BASF was effective at 2 % concentration as seed treatment for control of Cicer arietinum L wilt. At 1 % concentration the fungicide of Dhanuka was effective, as it protected the plant from wilt pathogen and there was 100 % plant stand.

At this concentration the same fungicide of other two companies i.e. Zuari and BASF was not effective as seed treatment to control the wilt disease indicating that the efficacy of the fungicide Carbendazim varies with the company brand at 1 % concentration. The results (table.9) indicate that the fungicide Captan was not effective to control the wilt disease, however the fungicide of the Zuari company could control the wilt disease to the extent of 66.66 percent at 2.0% concentration. The results (Table 10) indicate that the fungicide Metalxyl + Mancozeb was not at all effective as seed treatment to control the wilt disease (fig.2). Thus, under *in vitro* test for inhibition of *Fungal* growth of Cicer arietinum L wilt pathogen *F.o.f.sp .ciceri (Padwick) Matuo & Sato*, as seed dressing treatment and under in vivo test to control wilt incidence, the fungicide Carbendazim was found effective than other fungicides and among the companies Carbendazim of Dhanuka company was most effective. Several workers have also reported the effectiveness of Carbendazim in the control of Cicer arietinum L wilt pathogen. Taya *et al*., (1990) tested eight fungicides, alone or in combination with Thiram, as seed

treatment, pre-sowing soil drench and seed treatment + drenching after sowing with different levels of N and P and observed that increased level of P enhanced the effectivity of Carbendazim and Carbendazim + Thirum, applied as seed treatment, while increased level of N reduced the effectivity of fungicide. Sugha *et al*., (1995) evaluated 12 fungicides against Cicer arietinum L wilt pathogen under *in vitro* and *in vivo* and reported Carbendazim and Thirum alone or in combine as highly effective in inhibiting *in vitro* mycelial growth of the pathogen and in reducing wilt incidence under glasshouse and field conditions. De *et al*., (1996) found that coating of Cicer arietinum L seeds with Carbendazim at 0.2 % concentration was more effective in reducing wilt and increasing seed yield by 25.9 to 42.6%. Gupta *et al*., (1997) screened 6 fungicides against *Fusarium oxysporum f.sp.ciceri (Padwick) Matuo & Sato* and reported Carbandazim at 100mg/mL as most effective in inhibiting the growth of the fungus under in vitro condition. Poddar *et al.* (2004) evaluated 4 systemic fungicides viz. Carbendazim, propiconazole, tebuconazole and thiophanate methyl against *Fusarium oxysporium* and found that Carbendazim inhibited the maximum growth of the fungus under in vitro condition.

Mukhtar (2007) reported the chemical treatment with Benomyl (50WP) and Carbendazim(50WP) as most effective against *F.o.f.sp.ciceri(Padwick)Matuo & Sato.* Nikam *et al*., (2007) reported the chemical seed treatment with Thirum(0.15%) + Carbendazim(0.1) as most effective against chickpea wilt pathogen *F.o.f.sp.ciceri (Padwick)Matuo & Sato.* Devi Soma *et al*., (2008) observed Carbendazim and Vitavax as highly fungitoxic with 100 % inhibition of *F.oxysporum* at 100 mg/L and 200 mg/L concentration. Khilare *et al*., (2009) tested 9 fungicides against different isolates of *F. o. f. sp. ciceri(Padwick)Matuo & Sato* for their sensitivity. Among them, Carbendazim showed high efficacy at 1.61 mg/ml against highly virulent isolate followed by difenoconazole (197.64 mg/mL), Vitavax (3977 mg/ml), Thiophanate methyl (1254.67 mg/mL), Captan (7034.86 mg/mL) and Thirum (7087.01 mg/mL).

Muneeb Andrabi *et al*., (2011) found that Carbendazim at 100, 200, and 500 mg/mL concentrations caused maximum percent inhibition of mycelial growth of wilt pathogen of Cicer arietinum L under *in vitro* condition. Fungicides applied as seed treatment reduced disease incidence significantly. Subhani *et al*., (2011) tested fungitoxic effects of 6 fungicides viz. Benomyl, Derosal, Ridomil, Cabrio-Top, Vitavax and Prevent at four concentrations of 5, 10, 20 and 50 mg/L in poison food technique and reported a significant decrease in mycelial growth of the wilt pathogen fungus with an increase in fungicidal concentration. The most effective fungicide in inhibiting the growth of the fungus in descending order were Derosal, Benomyl, and vitavax as they caused 100, 95.81, 93.80 and 70.96 % reduction in mycelial growth respectively at 5 mg/L concentration. Ridomil and Prevent were least effective as they reduced 42.30 and 39.02 % mycelial growth respectively. Zacharia *et al*., (2012) reported maximum inhibition of *Fusarium* wilt under field condition at 0.3 % concentration followed by 0.2 and 0.1 % concentration of Carbendazim. Kamdi *et al*., (2012) found that Carbendazim seed treatment at 2 g/kg seed gave minimum wilt incidence (26.38) and maximum yield (13.47Q/ha). Baniani *et al*., (2016) found Carbendazim as effective seed treatment for germination, vigurity and protection of cotton seedling from seedling diseases.

The combination formulation involving both protectant and systemic fungicides like Captan and Carbendazim over the sole application was superior to reduce yield losses and avoid fungicidal resistance in wilt pathogen (Rashid *et al*., 2014). Patra *et al*., (2016) reportrd 100% fungal growth inhibition of chickpea wilt pathogen by fungicide Carbendazim at 1000 and 1500 mg/L concentration. Copperoxychloride exhibited least growth inhibition of 65.56% and 76.67% at the above concentrations. In vivo experiments, carbendazim was best for minimum wilt incidence of 9.66%. Golakiya *et al*., (2018) reported a combination of 12%carbendazim+ 63%Mancozeb as most effective followed by Carbendazim to have minimum PDI for wilt disease of Cicer arietinum L under field condition. Recently (Arshi Jamil and Shabbir Ashraf,2020) assessed four fungicides viz. Carbendazim, Captan, Thirum and Thiophenate for restricting the growth of wilt pathogen of Cicer arietinum L under in vitro, in pot, and under field condition, where the fungicide Carbendazim gave the best results. Seed treatment with carbendazim was more efficient in enhancing pod and nodule count per plant and Yield. Similarly, Asit *et al*. (2020) reported maximum inhibition of mycelial growth with a mean of 91% over control by carbendazim under in vitro study. In glasshouse assay, the combination of SA and carbendazim (10ug/mL) showed significant decrease in wilt of cotton.

Thus most of these workers have reported the effectiveness of Carbendazim in the control of wilt pathogen of Cicer arietinum L and the disease caused by it, nevertheless, none of these workers have tested the efficacy of Carbendazim and other seed protectant fungicides, company wise to report its efficacy. Our results, thus indicate that there was variation in the efficacy of the fungicide in the inhibition of fungal growth of *F.o.sp. ciceri (Padwick)Matuo & Sato* and the wilt disease caused by it among the fungicides and the company brand. These results are of great value in deciding the selection of fungicide and the company brand so as to achieve the 100 % control of the disease. Generally, in human medicine, the medical practitioner prescribes the medicine for the particular disease by the trade name of the medicine and not by the active technical ingredient/technical name of the medicine as the same medicine is available with various trade name which are specific to the manufacturing companies. However, for plant protection medicines, these are always prescribed with their technical name and not with the trade name. The present research paper, on the basis of its results, suggest to recommend the plant health medicines particularly fungicides by their trade name which are specific to the companies rather than the technical name of the fungicide. Similar kind of research for other fungicides and insecticides will pave a way in the fungicide use efficacy research and will be much helpful to reduce the pesticide pollution on the earth, immergence of resistance fungal species due to less effective fungicidal application in the ecosystem and save the crop from the pesticide residues for the better public health.

## Conclusion

The efficacy of seed protectant fungicides varies with or among the fungicides itself. A particular fungicide of different companies also varies in its efficacy in the inhibition of fungal growth of the pathogen and the disease caused by it. Therefore, the answer to the question does the efficacy of a fungicide varies with company brand name is in

affirmation and thus have its implication on plant disease control. Selection of seed protectant fungicide of a reputed company is necessary over the locally or lesser known companies to achieve the desired control of seed borne diseases.

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