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Evaluation of new molecules of fungicides against early blight (*Alternaria solani* (Ellis and Martin) Jones and Grout) of tomato (*Lycopersicon esculentum* Mill)

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Abstract
Field trials were conducted on chilli variety Lakshmi Hybrid for management of early blight (*Alternaria solani*) through new fungicide molecules. The pooled data of two year trials revealed that, minimum percent disease index (PDI) of early blight (4.30%; 2.00%, respectively) was observed with Chlorothalonil 75 WP @3.0 g/l. The data also indicated that foliar spray of Chlorothalonil 75 WP @2.0 g/l resulted in 5.23 and 2.47 PDI which proved to be the second effective treatment. However, highest fruit yield (14.25 t/ha; 16.00 t/ha) was observed with Chlorothalonil 75 WP @3.0 g/l, while the yield of chilli was less in untreated control (9.80 and 8.75 t/ha). The results also showed that Chlorothalonil 75 WP @3.0 g/l and Chlorothalonil 75 WP @6.0 g/l did not show any phytotoxic symptoms. These fungicide molecules even at higher doses do not manifest any phytotoxic symptoms and also exhibiting an appreciable increase in fruit yield of tomato.

Keywords: Tomato, Early blight, New fungicide molecules, Disease incidence, Yield

Introduction
Tomato (*Lycopersicon esculentum* Mill.) is a widely grown vegetable and occupies second important remunerable solanaceous vegetable crops after potato either for local consumption and exportation. It is native to South America and is widely cultivated in 140 countries of the world with an annual production of 16826000 metric tonnes. Area under tomato cultivation is 39,460 ha with an annual production of 1, 225, 870 metric tons (Anonymous, 2015) [3]. The fruits are consumed either fresh or cooked and are also used in large quantities to prepare soup, ketchup, puree paste and dehydrated powder. It contains pigment called lycopene which helps to prevent prostate cancer Tan *et al*, 2010 [37]; Lee *et al*, 2011 [25]. It is also an excellent source of vitamin C, a free radical scavenger and vitamin K in addition to several mineral nutrients required for good human health Borguin and Torres, 2009 [6]. There has been a gradual increase in the area under tomato while the production has been fluctuating due to various pest and diseases. There are several diseases on tomato caused by fungi, bacteria, viruses, nematodes and abiotic factors Balanchard, 1992 [5]; Gomaa, 2001 [14]; Abada *et al*, 2008 [1]. Among the fungal diseases, early blight caused by *Alternaria solani* (Ellis and Martin) Jones and Grout, is the most threatening one El-Abyad *et al*, 1993 [11]; Abdel-Sayed, 2006 [2] and Abada *et al*, 2008 [1], which causes great reduction in the quantity and quality of fruit yield.
The fungus causes disease in tomato, potato and brinjal. The causal organism is air borne and cause disease on foliage (leaf blight), stem (collar rot) and fruit (fruit rot) and can result in severe damage during all stages of plant growth and development Foolad *et al*, 2000 [12 disseminated by conidia (Datar and Mayee, 1981 [8]). It is increasingly becoming a limiting factor for successful cultivation of tomato and causes yield losses varies from 15-100% Sohi, 1984 [35]; Mathur and Shekhawat, 1986 [28]. Tomato crop is damaged due to severe infection of *A. solani* every year in India. The disease severity was recorded up to 90% in Varanasi region by Pandey *et al*, 2002. Primary methods of controlling early blight include preventing long periods of wetness on the leaf surface, cultural scouting, sanitation, and development of the host plant resistance with the application of fungicides Namanda *et al*, 2004 [30]; Kirk *et al*, 2005 [23]; Kumar and Srivastava, 2013 [24]. Cultivation of resistant varieties is the ultimate control of this disease.

Although heritable resistance has been reported for *A. solani* Holley *et al*, 1983 [17]; Herriot *et al*, 1986 [16]; Christ, 1991 [7], the disease is still primarily managed by use of foliar fungicides. However, frequent application of these fungicides over a period of time has led to the development of fungicidal resistance in *Alternaria* resulting in emergence of fungicidal resistant strains. Several fungicides have been recommended against early blight disease but still there is a need to widen the choice by introducing new molecules. The main objective of the present study are (i) to evaluate the bio-efficacy of Kavach 75 WP (Chlorothalonil 75% WP) against early blight disease in tomato and (ii) to determine the phytotoxic effect of Kavach 75 WP (Chlorothalonil 75% WP) on tomato crop.

Materials and Methods

The field experiments for the evaluation of fungicides were conducted at Morepalayam and Koothanatham village of Namakkal district during 2014-15. Twenty five days old tomato seedlings raised in portrays were transplanted to in a plot size of 3 x 2.7 m experimental plots, with row spacing of 60 cm and plant spacing of 45 cm. The experiment was laid out in randomized complete block design with three replications using variety Lakshmi hybrid. All recommended agronomic practices were also followed.

The details of treatments are: T_1- Three sprays of Kavach 75 WP (Chlorothalonil 75 % WP) @ 1 g/l ; T_2- Three sprays of Kavach 75 WP (Chlorothalonil 75 % WP) @ 2 g/l ; T_3-Three sprays of Kavach 75 WP (Chlorothalonil 75 % WP) @ 3 g/l ; T_4- Three sprays of Kavach 75 WP Chlorothalonil 75 % WP) @ 6 g/l ; T_5- Three sprays of Mancozeb 75% WP @2.5 g/l; T_6-Three sprays of Copper oxy chloride 50 WP @2.5 g/l; T_7- Zineb 75 WP@2.0 g/l;T_8- Untreated control.

Fungicide application treatments were done by Knapsack sprayer. Three sprays of fungicides were applied at regular intervals of ten, twenty and thirty days. Data on the disease severity was recorded after every fifteen days intervals. First observation on disease severity was recorded before the beginning of first spray and subsequent observations after first spray and before second and third spray and finally disease severity was recorded 105 days after planting (DAP). Five plants were selected randomly in each plot and observation on severity of the disease on the foliage was recorded using 0-5 scale of Horsefall and Barette, 1945 [18] and per cent disease index (PDI) was worked out using formula of Wheeler 1969 [38]. The fruit yield was also recorded.

Statistical analysis

All the experiments were of Randomized Block design (RBD) and repeated twice. The disease severity data was arcsine transformed before analysis of variance (ANOVA). Data were subjected to analyses of variance and treatment means were compared by an appropriate Duncan's multiple range test ($P<0.05$). The IRRISTAT package version 92-1, developed by the International Rice Research Institute Biometrics Unit, Philippines, was used for analysis.

Results and Discussion

The results of the two season trial clearly indicated that all the fungicides were found to be significantly superior over control in management of early blight of tomato. The disease management was better with increase in concentration of fungicides. The minimum disease intensity was observed with Chlorothalonil 75 WP @ 3.0 g/l (4.30%; 2.00%, respectively) followed by Chlorothalonil 75 WP @ 2.0 g/l (5.23%; 2.47%, respectively) (Table 1). However, the maximum disease intensity was observed with control (23.00%; 25.60%, respectively).The results are in agreement with the findings of Mishra (2012 [29]) reported that three sprays of Indofil M-45 at 10 days interval was found most effective in reducing leaf blight intensity to 58.5% followed by Indofil Z-78 and Chlorothalonil. Sudarshana *et al*. (2012 [36]) found that Carbendazim was most effective fungicide for controlling the early blight of tomato. Minimum disease severity of early blight of tomato (8.0%) and maximum fruit yield (16.9% t/ha) were recorded in Carbendazim + Mancozeb @ 0.2% followed by Mancozeb @ 0.2% and Iprodione + Carbendazim @ 0.2% (Singh *et al*, 1997 [34]). The minimum disease intensity was 8.2% with Carbendazim + Mancozeb @ 0.2% concentration followed by 11.4% with Mancozeb @ 0.2%, 15.2% with Iprodione + Carbendazim 0.2%, 18.4% with Metalaxyl + Mancozeb 0.2% and 20.8% Chlorothalonil 0.2% in field (Dushyant *et al*, 2014 [10]). The highest reduction in *Alternaria* leaf spot of tomato was achieved by applying Mancozeb @12 g/l of water at an interval of 7, 14, 21 and 28 days Gondal *et al*, [15] 2012.

Table 1: Efficacy of Chlorothalonil 75 WP on the incidence of early blight disease of Tomato Season-I (Sept to Dec 2014)

Treatments (g/lit)	Early blight (PDI)*			Yield (t/ha)*
	Before spray	After 3rd spray	Per cent decrease over control	
Chlorothalonil 75 WP @ 1.0	3.20 a	6.17 c (10.74)	73.17	12.43 c
Chlorothalonil 75 WP @ 2.0	3.27a	5.23 b (13.22)	77.26	13.94 a
Chlorothalonil 75 WP @ 3.0	3.23 a	4.30 a (11.97)	81.30	14.25 a
Mancozeb 75 WP @ 2.5	3.20 a	12.00 d (20.27)	47.82	11.67 e
Copper oxy chloride 50 WP @ 2.5	3.20 a	14.40 f (22.30)	37.39	12.05 d
Zineb 75 WP @ 2.0	3.20 a	13.67 e (21.70)	40.56	10.56 f
Control	3.13 a	23.00g (28.66)	-	9.80 g

*Mean of three replications. PDI - Per cent Disease Index.

Values in the parentheses are arc sine transformed values.

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Application of Mancozeb @12 g/l and 16 g/l of water showed best results for the control of early blight of tomato by several workers Maheswari *et al*, 1991 [27]; Naveenkumar *et al*, [31]

2001; Kapsa and Osowski, 2003 [22]. Two sprays of Mancozeb @0.5 per cent or Propiconazole @0.05 per cent were most effective for reducing the early blight of tomato under field condition. These fungicides could lower down the disease intensity from 54.02 per cent (Control) to 35.27 and 35.32 per cent Sali *et al*, 2010 [33]. Jambhulkar *et al*. 2012 [21] reported that foliar application with Azoxystrobin 23% SC showed promising results by reducing disease severity of leaf blight by 38.9% as compare with control. Archana and Jamadar 2014 [4] also reported that leaf blight of tomato can be effectively controlled by spraying Propiconazole which reduced disease incidence (PDI-4.37%) followed by Thiophanate methyl and Hexaconazole recording 11.70 and 14.47 per cent disease index, respectively. The disease severity of *Alternaria* leaf spot were reduced in cabbage treated with Tebuconazole (4.62%), Trifloxystrobin +Tebuconazole (6.01%) and Propiconazole (9.45%), which were found best among the other fungicides Dinh Viet *et al*, 2015 [9].

Among the various treatments conducted in the field trial-I and II, Chlorothalonil 75 WP @ 3.0 g/ lit of water found significantly superior in giving highest fruit yield of tomato (14.25 t/ha; 16.00 t/ha). The next best treatment was Chlorothalonil 75 WP @ 2.0 g/ lit (13.94 t/ha and 14.49 t/ha). The control recorded the lowest fruit yield of 9.80 t/ha and 8.75 t/ha (Table 1 and Table 2).

Table 2: Efficacy of Chlorothalonil 75 WP against Early blight disease in Tomato Season- II (Jan-April 2015)

Treatments (g/lit)	Early blight (PDI)*			Yield (t/ha)*
	Before spray	After 3rd spray	Per cent decrease over control	
Chlorothalonil 75 WP @ 1.0	2.23 a	3.80 e (6.62)	85.15	11.76 d
Chlorothalonil 75 WP @ 2.0	2.30 a	2.47 a (9.04)	90.35	14.49 b
Chlorothalonil 75 WP @ 3.0	2.23 a	2.00 a (8.13)	92.18	16.00 a
Mancozeb 75 WP @ 2.5	2.23 a	4.80 b (12.66)	81.25	12.89 c
Copper oxy chloride 50 WP @ 2.5	2.30 a	9.20 d (17.66)	64.06	10.85 f
Zineb 75 WP @ 2.0	2.27 a	8.87 c (17.33)	65.35	11.10 e
Control	2.30 a	25.60 f (43.20)	-	8.75 g

*Mean of three replications. PDI - Per cent Disease Index.

Values in the parentheses are arc sine transformed values.

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Pyraclostrobin significantly reduced the early blight and increased the yield in tomato and potato has been reported previously by many workers Ivey *et al*, 2004 [20]; MacDonald *et al*, 2007 [26]; Ganeshan and Chethana, 2009 [13]. Four sprays of Carbendazim + Mancozeb @ 0.2% starting from disease appearance could be exploited as an good strategy for reducing the severity of early blight and increasing fruit yield of tomato under field conditions Dushyant *et al*, 2014 [10]. Hosagoudar *et al*. 2014 [19] reported that *Alternaria* leaf spot disease in Bt cotton by Propiconazole recorded significantly increased yield of 2894.5 kg per ha. The good quality of cabbage heads with higher yield were obtained in Tebuconazole, Trifloxystrobin + Tebuconazole, Mancozeb and Propiconazole sprayed plots, compared to untreated check Dinh Viet *et al*, 2015 [9]. The above results lend support to the present findings.

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