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Management of okra powdery mildew through agrochemicals

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Abstract
To know the field performance of selected phytoproduct, phytoextracts, fungicides and insecticide against powdery mildew disease the field experiment was conducted at N. M. College of Agriculture Farm during late *Rabi* season of the year 2014-15 and 2015-16. The results showed that hexaconazole @ 0.005% recorded highest per cent disease control (92.48 %) of powdery mildew followed by wettable sulphur @ 0.2% (87.21 %), triazophos @ 0.05% (79.68 %) and trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (78.86 %). Whereas, *Cassia tora* seed extract @ 1% (61.33 %), *C. tora* leaf extract @ 1% (59.79 %) and neem oil @ 0.0006 (58.33 %) showed the fungicidal effect and minimized the disease. Similarly, significantly higher fruit yield was recorded in fungicidal treatment of hexaconazole @ 0.005% and triazophos @ 0.05% in comparison to other treatments.

Keywords: powdery mildew, okra, hexaconazole, triazophos, *cassia tora* and neem oil

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench], is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. This crop is suitable for cultivation as a garden crop as well as on large commercial farms. The area under okra cultivation in India is 535.00 (000 ha) with production of 6478.97 (000 MT) & productivity of 12.10 MT/ha (Anonymous, 2015) [2]. In Gujarat, okra is grown throughout the year providing continuous and good source of income to the farmers. It is mainly grown in Vadodara, Surat, Junagadh, Banaskantha and Bhavnagar districts. It occupies an area of 65.41 thousand hectares with a production of 717.25 thousand metric tonnes having average productivity of 10.90 MT/ha (Anonymous, 2015) [2]. Many factors responsible for yield loss of the crop, one of them is the diseases are major constraints for low yield of okra (Sastry, 1974) [18]. A number of fungal, bacterial, viral diseases have been reported in India. Among the fungal diseases affecting okra crop, powdery mildew caused by *Erysiphe cichoracearum* DC is most important disease causes considerable yield losses. The occurrence of the disease has been reported from Mexico (Diaz-Franco, 1999) [5]. In India, the disease has been reported to occur in Delhi (Prabhu *et al*., 1971) [16], Karnataka (Sohi and Sokhi, 1973) [21], Himachal Pradesh (Raj *et al*., 1992) and Maharashtra (Jambhale and Nerkar, 1983). The disease initiates as white minute patches first on the upper surface of lower older leaves and then spreads to younger ones. Grayish white powdery coating is visible on severely affected leaves. Leaves finally show necrosis resulting in withering, drying and defoliation. It is not appearing on stem, branches and fruits. Powdery mildew affects plants of all growth stages and may result yield losses to the tune of 17 to 86.6 per cent (Sridhar and Sinha, 1989) [23]. Crop yield losses are significant under favourable weather conditions if the infection takes place in early stages of plant growth (Gupta and Thind, 2006) [8]. The loss due to powdery mildew is proportionate to the disease intensity and varies considerably depending on the stage of the plant growth at which disease occurs. Fungicidal trials conducted by many workers equivocally support the fact that several effective fungicides are available for management of powdery mildew. But precise knowledge of when to expect first appearance of disease and its subsequent progress, based on weather conditions and susceptibility of different developmental stage, would aid growers in ascertaining optimum time of fungicidal applications.

Material and Method

To find out the most suitable phytoextract or/and fungicides for the disease, a field trial was conducted during *rabi*, 2014 and 2015 at College Farm, N.M.C.A., N.A.U., Navsari, with susceptible variety GAO-5. The detail of the experiment is given in table 1. The use of plant extracts and phytoproducts is gaining attention due to their proven nature specificity, bio degradability, low toxicity and minimum residual toxicity in the ecosystem. So, plant extract of *Cassia tora* (Chakunda) was used in present study which have broad-spectrum antifungal properties and are effective against both biotrophic and necrotrophic pathogens. Specially, in *Cassia tora* have Anthraquinones (emodin, physcion and rhein), showed antifungal activity against *Erysiphe graminis* (Jain and Patil, 2010) [9].

For preparation of phytoextract of *Cassia tora* fresh healthy leaves and seeds were collected from the Research farm, NAU, Navsari. These were washed thoroughly with clean tap water and subsequently with sterilized distilled water. Fifty grams of leaves/seeds was minced with the help of a grinder and was thoroughly mixed in 50 ml sterilized distilled water. The phytoextracts were filtered through double layered muslin cloth, filled in 150 ml conical flask and plugged with non-absorbent cotton. These filtered phytoextracts were autoclaved at 121^{0}C temperature for 20 minutes for sterilization.

All the recommended agronomical practices were adopted for raising the crop. Two sprays were given. First at the initiation of disease and thereafter 20 days of interval. Ten plants were randomly selected from each plots and labelled for subsequent evaluations. Per cent disease index (PDI) was calculated by using following formula proposed by Wheeler (1969) [25].

$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of the individual disease ratings}}{\text{Total number of leaves observed X Maximum grade}} \text{ X } 100$$

The yield of healthy fruits was also recorded at each picking in every plot and total yield data thus obtained were analysed Statistically.

Table 1: Treatments Details

Treatments	Chemical or plant product/extract	Trade name	Formulation	Concentration (%)	Quantity (ml or g/10 liter)
T1	Neem oil	Vanguard	EC (0.15% Azadirachtin)	0.0006	40
T2	*Cassia tora* leaf extracts	-	-	1	100
T3	*Cassia tora* seed extracts	-	-	1	100
T4	Triazophos	Hostathion	40 EC	0.05	12.5
T5	Hexaconazole	Hexattaf Plus	5 EC	0.005	10
T6	Wettable Sulphur	Sulfex Gold	80WP	0.2	25
T7	Trifloxystrobin 25% w/w + tebuconazole 50% w/w	Nativo	75WG	0.05	6.6
T8	Control			-	

Results and Discussion

The results recorded about per cent disease intensity and fruit yield are presented in Table 2, respectively. The year wise result were discussed as under

Table 2: Efficacy of various plant product/extracts, fungicides and insecticide against powdery mildew of okra

T. no.	Per cent Disease intensity											
	2014-15				2015-16				Pooled			
	Before 1st spray	20 days after 1st Spray	20 days after 2nd spray	Maturity	Before 1st spray	20 days after 1st spray	20 days after 2nd spray	Maturity	Before 1st spray	20 days after 1st spray	20 days after 2nd spray	Maturity
T1	2.24 (5.06*)	24.19 (15.80)	31.24 (25.92)	33.45 (29.38)	2.04 (4.19)	25.31 (17.28)	28.95 (22.46)	34.43 (30.98)	2.14 (4.63)	24.75 (16.54)	30.12 (24.19)	33.94 (30.18)
T2	2.06 (4.32)	22.79 (14.07)	32.89 (28.52)	34.06 (30.37)	2.02 (4.07)	22.44 (13.70)	28.46 (21.72)	34.20 (30.61)	2.04 (4.20)	22.62 (13.88)	30.73 (25.12)	34.13 (30.49)
T3	2.27 (5.18)	22.42 (13.58)	31.96 (27.04)	32.12 (27.28)	2.02 (4.07)	23.12 (14.44)	28.70 (22.09)	32.58 (28.02)	2.15 (4.63)	22.77 (14.01)	30.36 (24.56)	32.36 (27.65)
T4	2.04 (4.20)	16.16 (6.79)	22.94 (14.19)	23.62 (15.06)	2.10 (4.44)	15.94 (6.54)	20.99 (11.85)	24.47 (16.17)	2.07 (4.32)	16.05 (6.66)	21.98 (13.02)	24.05 (15.61)
T5	2.01 (4.07)	11.96 (3.33)	12.67 (3.82)	13.62 (4.57)	2.07 (4.32)	12.17 (3.45)	13.16 (4.19)	15.10 (5.80)	2.04 (4.20)	12.07 (3.39)	12.92 (4.00)	14.38 (5.18)
T6	2.22 (4.94)	14.68 (5.43)	15.67 (6.30)	18.68 (9.26)	2.19 (4.82)	14.40 (5.19)	15.66 (6.30)	20.58 (11.35)	2.21 (4.88)	14.55 (5.31)	15.66 (6.30)	19.65 (10.30)
T7	1.99 (3.95)	18.64 (9.26)	21.11 (11.97)	23.72 (15.19)	1.92 (3.70)	18.56 (9.14)	19.24 (9.87)	24.38 (16.05)	1.95 (3.82)	18.61 (9.19)	20.20 (10.92)	24.06 (15.62)
T8	2.22 (4.94)	39.67 (39.75)	49.43 (56.66)	58.46 (71.60)	2.28 (5.19)	40.96 (41.97)	48.76 (55.55)	60.07 (74.07)	2.25 (5.06)	40.32 (40.86)	49.10 (56.11)	59.26 (72.83)
S. Em. ±	0.07	0.61	1.01	0.44	0.09	0.73	0.59	0.43	0.07	0.62	0.70	0.42
C.D. (0.05)	NS	1.86	3.07	1.34	NS	2.21	1.78	1.31	NS	1.89	2.12	1.28
C.V. %	6.08	4.99	6.43	2.58	7.52	5.85	3.99	2.43	6.17	5.01	4.58	2.43

*Figures in parenthesis are original value

2014-15

The powdery mildew intensity (PDI) recorded at disease initial stage (before spraying) was ranged from 3.95 to 5.18 per cent. Two sprays of different fungicides, phytoproduct, phytoextracts and insecticide were under taken at initiation of disease and second on an interval of 20 days. The per cent disease intensity was recorded before first spray, 20 days after first spray (before second spray), 20 days after second spray and maturity stage. The perusal of data presented in table 4.35 revealed that before spray, all the treatment showed non-significant differences with PDI i.e. the disease appearance was more or less similar.

It is clear from the data that all the treatments were found significantly superior over control for the per cent disease intensity after 20 days of first spray (before second spray). The minimum per cent disease intensity (3.33 %) was observed in the plots treated with hexaconazole @ 0.005% followed by wettable sulphur @ 0.2% (5.43 %) which was at par with insecticide triazophos @ 0.05% (6.79 %). Whereas, *Cassia tora* seed extract @ 1%, *C. tora* leaf extracts @ 1% and neem oil @ 0.0006% were found to reduced the disease and at par with each other but these were shown significant difference with fungicides and triazophos.

Similarly, 20 days after second spraying, the per cent disease intensity was found to be reduced significantly by all the treatments over respective un-sprayed control. Minimum disease intensity (3.82 %) was recorded by hexaconazole @ 0.005% which was at par with wettable sulphur @ 0.2% (6.30 %). The treatment of trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (11.97 %) triazophos @ 0.05% (14.19 %) were found non-significant. The neem oil @ 0.0006, *C. tora* seed extract @ 1% and *C. tora* leaf extract @ 1% were also noted fungicidal effect on disease and at par with each other but significantly less effective as compared to fungicides and triazophos.

At maturity stage, all the treatments found significantly superior by reducing per cent disease intensity over respective un-sprayed control. Significantly lowest disease intensity (4.57 %) was observed in hexaconazole @ 0.005% followed by treatment of wettable sulphur @ 0.2% (9.26 %). The treatment of triazophos @ 0.05% (15.06 %) was at par with trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (15.19 %). Whereas, *C. tora* seed extract @ 1%, neem oil @ 0.0006 and *C. tora* leaf extract @ 1% were found significantly less effective as compared to fungicides and triazophos but at par with each other.

2015-16

The data presented in Table 2 revealed that Per cent disease intensity was significantly reduced by all the treatments over control (No spray) at before second spray, 20 days after second spray and at maturity stage. The disease intensity before first spray was found non-significant among the treatment.

Before second spray, among the eight treatments, the lowest disease intensity (3.45 %) was noted in the plots treated with hexaconazole @ 0.005% followed by wettable sulphur @ 0.2% (5.19 %) which was at par with triazophos @ 0.05% (6.54 %). The *Cassia tora* leaf extract @ 1% (13.17 %), *C. tora* seed extract @ 1% (14.44) and neem oil @ 0.0006 (17.28 %) were found to be minimized the disease and these were shown significantly differences with fungicides and triazophos but at par with each other.

After 20 days of 2nd spray, all the treatments were found significantly superior over control by reducing per cent disease intensity. Significantly minimum disease intensity (4.19 %) was recorded by hexaconazole @ 0.005% followed by wettable sulphur @ 0.2% (6.30 %) and trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (9.87 %).The *Cassia tora* leaf extract @ 1%, *C. tora* seed extract @ 1% and neem oil @ 0.0006 were also found at pat with each other and less effective as compared to fungicides and triazophos.

At maturity stage, significantly minimum disease intensity (5.80 %) was recorded by hexaconazole @ 0.005% followed by treatment with wettable sulphur @ 0.2% (11.35 %). The treatment of trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (16.05 %) was found at par with triazophos @ 0.05% (16.17 %). The *Cassia tora* seed extract @ 1% (28.02 %), *C. tora* leaf extract @ 1% (30.61 %) and neem oil @ 0.0006 (30.98 %) were found at par with each other and showed fungicidal effects on disease but comparatively less effective then fungicides and triazophos.

Pooled

The pooled data of 2014-15 and 2015-16 indicated that all the treatments were found significantly superior over control for the per cent disease intensity at before second spray, 20 days after second spray and at maturity stage of the crop. The disease intensity before first spray was found non-significant among the treatment.

Before second spray *i.e*. 20 days after first spray, among the eight treatments, lowest disease intensity (3.39 %) was observed in hexaconazole @ 0.005% followed by treatment with wettable sulphur @ 0.2% (5.31 %) which was at par with triazophos @ 0.05% (6.66 %). Whereas, *C. tora* leaf extracts @ 1% (13.88 %), *C. tora* seed extracts @ 1% (14.01 %) and neem oil @ 0.0006 (16.54 %) were found at par with each other and revealed less effective as compared to fungicides and triazophos.

At 20 days after 2nd spray, significantly minimum disease intensity (4.00 %) was observed in hexaconazole @ 0.005% in comparison to wettable sulphur @ 0.2% (6.30 %). The phytoproduct neem oil @ 0.0006 (24.19 %), *C. tora* seed extract @ 1% (24.56 %) and *C. tora* leaf extract @ 1% (25.12 %) were also found at par with each other but significantly less effective than fungicides and triazophos.

At maturity stage, all the treatment were found significantly superior over control. The minimum disease intensity (5.18 %) was exhibited by hexaconazole @ 0.005%. The next best treatment was wettable sulphur @ 0.2% with 10.30 per cent disease intensity. The triazophos @ 0.05% (15.61 %) was found at par with fungicides trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (15.62 %).

The phytoproducts neem oil @ 0.0006 (30.18 %) and leaf and seed extracts of *Cassia tora* @ 1% were revealed non-significant differences with each other. The per cent disease intensity was found to be minimized but comparatively less effective than fungicides and triazophos.

The result in terms of per cent disease control presented in Fig 1 revealed that hexaconazole @ 0.005% recorded highest per cent disease control of powdery mildew followed by wettable sulphur @ 0.2%, triazophos @ 0.05% and trifloxystrobin 25% w/w + tebuconazole 50% w/w (Nativo 75WG) @ 0.5%. Whereas, *C. tora* seed extract @ 1%, neem oil @ 0.0006 and *C. tora* leaf extract @ 1% gave less disease control as compared to other treatment.

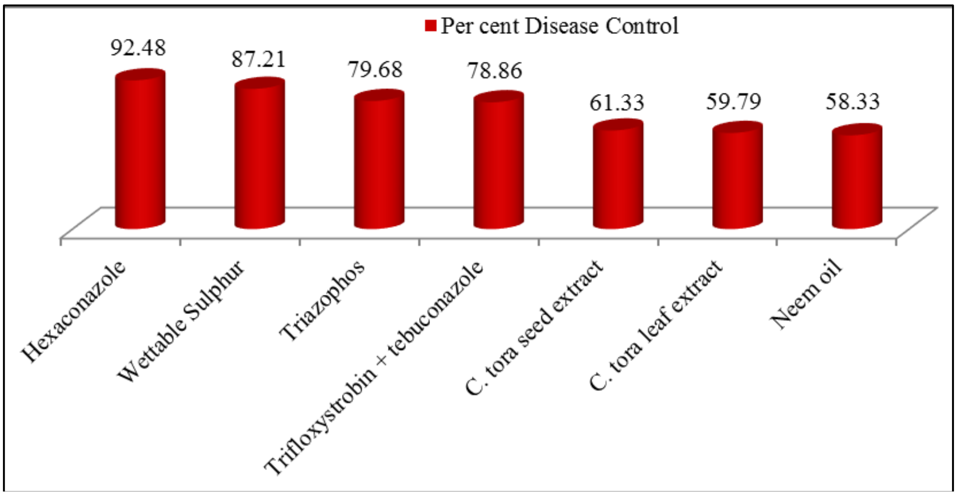

Fig 1: Per cent Disease control by different treatment

Yield

During 2014-15, fruit yield was significantly increased in all the treatments over the control. It was significantly higher (104.48 q/ha) in hexaconazole @ 0.005% which was at par with triazophos @ 0.05% (103.44 q/ha). Next best in order to merit was trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (93.55 q/ha) which was at par with wettable sulphur @ 0.2% (93.53 q/ha). The *Cassia tora* leaf extract @ 1% (88.84 q/ha), neem oil @ 0.0006 (87.73 q/ha) and *C. tora* seed extract @ 1% (87.47 q/ha) also gave better yield than control and found at par with each other yielded as compared to fungicides and triazophos (Table: 3).

Similarly, during 2015-16, fruit yield was significantly increased in all the treatments over the control. The plot treated with hexaconazole @ 0.005% recorded significantly maximum yield (108.24 q/ha) which was at par with triazophos @ 0.05% (107.63 q/ha). The wettable sulphur @ 0.2% (94.58 q/ha) and trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (92.91 q/ha) were at par with each other. The *Cassia tora* leaf extract @ 1% (86.32 q/ha), *C. tora* seed extract @ 1% (84.58 q/ha) and neem oil @ 0.0006 (84.40 q/ha) were found at par with each other and least yield as compared to fungicides and triazophos.

The pooled data of yield revealed that fruit yield was significantly higher in all the treatments over the control. Among eight treatments, hexaconazole @ 0.005% gave significantly maximum fruit yield (106.36 q/ha) which was at par with triazophos @ 0.05% (105.71 q/ha). The treatment wettable sulphur @ 0.2% (94.06 q/ha) was found at par with trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (93.24q/ha). The *Cassia tora* leaf extract @ 1% (87.59 q/ha), neem oil @ 0.0006 (86.07 q/ha) and *C. tora* seed extract @ 1% (86.03 q/ha) were found at par with each other and significantly increasing fruit yield over control but observed least yielded than fungicides and triazophos.

The result in terms of per cent yield increased over control depicted in Fig 2, revealed that hexaconazole @ 0.005% and triazophos @ 0.05% increased maximum fruit yield as compared to rest of the chemicals and phytoextracts against powdery mildew. The treatments *viz.*, wettable sulphur @ 0.2%, trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5%, neem oil@ 0.0006, *C. tora* seed extract @ 1%, and *C. tora* leaf extract @ 1% were also found to be effective to increased fruit yield over control.

The results were in agreement with several workers. Shivana *et al*. (2006) found that penconazole and hexaconazole effectively manage powdery mildew of okra. Hexaconazole belongs to fungicidal group Triazoles which interfere with the biosynthesis of fungal sterols and inhibit ergosterol biosynthesis. Ergosterol is essential to the structure of cell wall and its absence causes irreparable damage to the cell wall and fungus dies. They will also interfere in conidia and haustoria formation. They change the sterol content and saturation of the polar fatty acids leading to alterations in membrane fluidity and behaviour of membrane bound enzymes (Nene and Thapliyal (1993) [15], Amresh *et al*. (2013) and Karuna *et al*. (2015) [10].

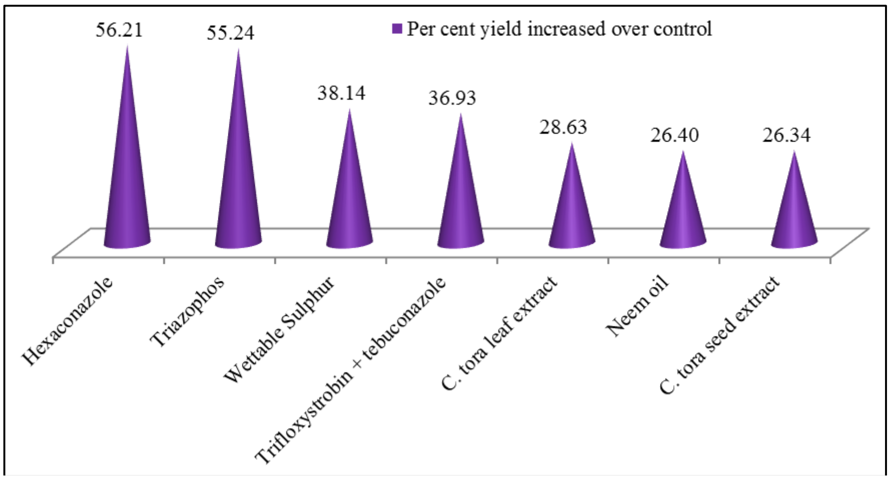

Fig 2: Per cent yield increased over control by different treatment

Other triazole fungicides *viz*., triadimefon, tebuconazole, penconazole, propiconazole and triadimefon also effective against powdery mildew of okra (Naik and Nagaraja (2000) [13], Vijaya (2004) [24], Rehman and Bhattiprolu (2005) [17], Shivanna *et al.* (2006), Bachihal *et al*. (2011) and Khalikar *et al*., 2011) [11]. Wettable sulphur also found effective against okra powdery mildew is mainly due to emission of sufficient vapors to prevent growth of fungal spores several millimeters from deposit on leaves repoted by Gaikwad and Karkeli (1994) [7], Shivana *et al*. (2006) and Dhutraj (2011) [4]. Inhibitory effect of triazophos against powdery mildew is also reported by Singh (1987) and Solanki (1995) [22].*Cassia tora* have Anthraquinones (emodin, physcion and rhein), which showed antifungal activity against *E. graminis* (Jain and Patil, 2010) [9]. Manas *et al*. (2005) [12] stated that plant extract of *C. tora* and *C. sophera* completely inhibited conidial germination in powdery mildew of mulberry.

Neem seed kernel extracts (5%) effectively manage the powdery mildew of okra (Vijaya 2004) [24]. The chemical basis of this antifungal activity has been attributed with the presence of oil in parts of *A. indica*. Singh *et al*. (2010) observed that nimbicidin (20.7%) proved most effective against powdery mildew of mustard. Neem leaf extract as foliar spray was effective against powdery mildew fenugreek and sunflower (Dinesh *et al*., 2015 and Narendra *et al*., 2015) [6, 14].

Table 3: Efficacy of various plant product/extracts, fungicides and insecticide on fruit yield of okra

Tr. no.	Chemical or plant product/extract	Yield (q/ha)		
		2014-15	**2015-16**	**Pooled**
T1	Neem oil	87.73	84.40	86.07
T2	*Cassia tora* leaf extracts	88.84	86.32	87.59
T3	*Cassia tora* seed extracts	87.47	84.58	86.03
T4	Triazophos	103.77	107.63	105.71
T5	Hexaconazole	104.48	108.24	106.36
T6	Wettable Sulphur	93.53	94.58	94.06
T7	Trifloxystrobin 25% w/w + tebuconazole 50% w/w	93.55	92.91	93.24
T8	Control	68.57	67.60	68.09
S. Em. ±		1.49	0.75	0.95
C.D. (0.05)		4.57	2.32	2.90
C.V. %		2.84	1.45	1.80

Conclusion
From the result of this experiment we can concluded that the management studies against powdery mildew of okra showed hexaconazole @ 0.005% recorded highest per cent disease control (92.48 %) of powdery mildew followed by wettable sulphur @ 0.2% (87.21 %), triazophos @ 0.05% (79.68 %) and trifloxystrobin 25% w/w + tebuconazole 50% w/w @ 0.5% (78.86 %). Whereas, *Cassia tora* seed extract @ 1% (61.33 %), *C. tora* leaf extract @ 1% (59.79 %) and neem oil @ 0.0006 (58.33 %) showed the fungicidal effect and minimized the disease. Similarly, significantly higher fruit yield was recorded in fungicidal treatment of hexaconazole @ 0.005% and triazophos @ 0.05% in comparison to other treatments.

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