

Evaluation of New Fungicides for the Management of Mango Anthracnose Disease Caused by *Colletotrichum Gloeosporioides*

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Abstract

A field experiment was conducted at the field of Plant Pathology Division, Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Jamalpur-2000, Bangladesh during February to July 2024 to assess the efficacy/effectiveness of thirty-five (35) new fungicides received from Pesticide Technical Advisory Committee (PTAC), Bangladesh with control treatment against anthracnose disease of mango. Most of the fungicides under inspection were able to control the disease successfully. This study suggests that fungicidal spray significantly affected the development of anthracnose in mangoes. Most of the fungicides used in this study were successful in preventing anthracnose, but they all decreased the disease's incidence and severity to varying degrees when compared to the control. Efficacy of different new fungicides ranged from 68.65 to 99.17%. Thirty-five (35) fungicides inhibited the disease by over 90%. However, only five (5) fungicides were able to inhibit the disease by less than 80%. Regarding the effectiveness of several new fungicides, the following efficient fungicidal treatments are recommended in order of higher to lower efficacy: Azoxystrobin 20% + Difenoconazole 12.5% SC > Carbendazim 50% WDG > Trifloxystrobin 25% + Tebuconazole 50% WDG > Tricyclazole 75% WP > Mancozeb 50% + Carbendazim 25% 75 WP. Most of the fungicides that were being studied were successful in controlling the disease. According to the study, fungicides that managed the disease increased fruit yields and, as a result, yielded the highest profits. Azoxystrobin 20% + Difenoconazole 12.5% SC was the most effective spray over control, followed by Carbendazim 50% WDG and Trifloxystrobin 25% + Tebuconazole 50% WDG. The findings demonstrated the benefits of controlling mango anthracnose with fungicides. The best methods to prevent mango anthracnose and guarantee effective mango cultivation, according to the mango producers, are to spray Azoxystrobin 20% + Difenoconazole 12.5% SC, Carbendazim 50% WDG, and Trifloxystrobin 25% + Tebuconazole 50% WDG.

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INTRODUCTION

One of the most significant and well-liked fruits in Bangladesh and other tropical and subtropical nations is the mango (*Mangifera indica* L.). Mango

fruit is prone to numerous diseases, just like other field crops. The most prevalent and significant field and post-harvest disease of mangos is anthracnose, which is caused by *Colletotrichum gloeosporioides* (Penz.) Fitzell & Peak (1984) [1]. According to Prusky (1991) [2], it is the primary factor restricting fruit yield. Young leaves and inflorescences are especially vulnerable to the disease. In addition to causing quiescent infections in developing fruits that manifest symptoms on ripening fruits throughout the post-harvest period, it can harm the leaves and flowers Muirhead *et al.* (1984) & Dodd *et al.* (1989) [3, 4]. The next major post-harvest disease after anthracnose is stem-rot, which is brought on by *Lasiodiplodia theobromae* (Pat.). According to Singh and Chaundawat (1991) [5], these diseases might decrease mango fruit yield by 25 to 30%. According to Quroshi and Meah (1991) [6], stem-end rot alone can cause a 15% loss in harvested mangoes. Mango post-harvest infections can be prevented in part by using fungicides before harvest. Mancozeb, Chlorothalonil, and Ferbam were shown to be similarly effective as field spray against mango anthracnose in Florida, according to Spalding (1982) [7]. Anthracnose was successfully controlled by field spraying copper and mancozeb (Dithane-M-45) [8]. Ahmed *et al.* (1991) [9] stated that Dithane-M-45 was the best fungicide to suppress anthracnose, while Mortuza *et al.* (2000) [10] found that mango fruits sprayed with Carbendaim (Bavistin) at a rate of 0.1% during the pre-harvest stage had the lowest incidence and severity of the disease. According to Mortuza *et al.* (2003) [11], pre-harvest mancozeb spraying at a dosage of 3 g/Litre totally stopped post-harvest anthracnose from developing mango fruits for up to 15 days following harvest. There are still very few reports regarding how fungicide use before the harvest affects pre- and post-harvest anthracnose disease in Bangladesh. Considering what had happened, an effort was made to investigate the effectiveness of several new fungicides against pre- and post-harvest anthracnose diseases of mango.

MATERIALS AND METHODS

A field experiment was conducted at the field of Plant Pathology Division, Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Jamalpur-2000, Bangladesh during February to July 2024 to assessment the efficacy/effectiveness of thirty-five (35) new fungicides received from Pesticide Technical Advisory Committee (PTAC), Bangladesh with control treatment against anthracnose disease of mango. The investigation was performed from February to July 2024. The spray commenced on different mango varieties/lines of 5-6 years old established tree in a mango orchard when the panicle size was 10-15 cm long. To prevent flower damage by insect pests, Ripcord 10 EC (Cypermethrin) 1 ml/litre was mixed with all the fungicides at first spray. The 1st spray was performed on 30.03.2024, 2nd spray on 12.05.2024 and continued up to the harvest of the fruit at 15 days interval. Furthermore, one spray of insecticide on 02.04.2024 (imidacloprid group) was done. Thirty-five (35) new fungicides from different groups were included to assess the efficacy against pre- and post-harvest anthracnose disease of mango. Details of the fungicide treatments, including their doses, are shown in Table 1. Fungicides were evaluated as their ability to prevent pre- and post-harvest anthracnose development which causes severe rot in mango fruits. At every spray schedule, control plants were sprayed with only water. Fungicidal spray was stopped 15 days before harvest of fruits. The field evaluation data was recorded before harvest. Randomly selected 21 fruits were harvested at full maturity from each treatment. Harvested treated fruits along with the untreated control were allowed to ripe in natural condition at room temperature (27–34°C). Disease incidence and Severity was recorded 8 days after harvest. The development of anthracnose on the harvested fruit was recorded 8 days after harvest following a standard severity scale (0-5) developed by Bondad *et al.* (1980) [12]. Percent disease incidence (PDI) was measured from percent fruit area covered by the disease. To evaluate the effectiveness of the chemicals, the severity of diseases was measured by calculating the percentage disease incidence (PDI) according to the formula of Singh (1984) [13]. The disease incidence was calculated using the following formula.

$$\text{Disease incidence (\%)} = \frac{\text{No. of infected plants}}{\text{Total no. of plants}} \times 100$$

Data on different traits (plant height, base girth, canopy spread (N-S & E-W), number of primary branches, tree volume, percent disease incidence, percent disease severity, percent efficacy of different new fungicides, number of fruits per plant, individual fruit weight, yield (kg/plant), fruit length, fruit

breadth, weight of peel, thickness of pulp, weight of stone, stone length, stone breadth, stone thickness, TSS, and edible portion) were recorded (Table 2, 3 & 4) and recorded characters were statistically analyzed following open-source programme 'R' [14].

Tree volume was determined by following formula:

$$\text{Tree volume} = \frac{1}{6} \pi \times \text{height} \times (2r)^2$$

Where, $2r = \frac{(E-W \text{ canopy}) + (N-S \text{ canopy})}{2}$

Table 1. List of treatments used in the investigation with fungicide chemical composition (a. i.) and dose.

Treatments	Fungicide chemical composition (a. i.)	Dose
T ₁	Trifloxystrobin 25% + Tebuconazole 50% WDG	0.5 gm/L of water
T ₂	Carbendazim 50% WDG	2.0 gm/L of water
T ₃	Tebuconazole 50% + Trifloxystrobin 25% WDG	0.5 gm/L of water
T ₄	Azoxystrobin 20% + Difenconazole 12.5% SC	1.0 ml/L of water
T ₅	Carbendazim 50% WDG	2.0 gm/L of water
T ₆	Tricyclazole 75% WP	2.0 gm/L of water
T ₇	Difenconazole 12.5% + Azoxystrobin 20% SC	1.0 ml/L of water
T ₈	Mancozeb 80% WP	2.0 gm/L of water
T ₉	Azoxystrobin 20% + Difenconazole 12.5% SC	1.0 ml/L of water
T ₁₀	Azoxystrobin 20% + Difenconazole 12.5% SC	1.0 ml/L of water
T ₁₁	Carbendazim 50% WDG	2.0 gm/L of water
T ₁₂	Difenconazole 125 g/L w/v + Azoxystrobin 200 g/L w/v	1.5 ml/L of water
T ₁₃	Copper Hydroxide 77% WP	1.0 gm/L of water
T ₁₄	Azoxystrobin 20% + Difenconazole 12.5% SC	1.0 ml/L of water
T ₁₅	Mancozeb 64% + Cymoxanil 8% WP	2.0 gm/L of water
T ₁₆	Azoxystrobin 20% + Tebuconazole 15% SC	1.0 ml/L of water
T ₁₇	Mancozeb 80% WP	3.0 gm/L of water
T ₁₈	Mancozeb 80% WP	2.0 gm/L of water
T ₁₉	Pyraclostrobin 25% SC	2.0 ml/L of water
T ₂₀	Mancozeb 80% WP	2.0 gm/L of water
T ₂₁	Propineb 70% + Dimethomorph 10% WP	3.0 gm/L of water
T ₂₂	Azoxystrobin 20% + Difenconazole 12.5% SC	1.0 ml/L of water
T ₂₃	Hexaconazole 10% SC	0.5 ml/L of water
T ₂₄	Tricyclazole 20% + Hexaconazole 10% SC	1.0 ml/L of water
T ₂₅	Mancozeb 64% + Cymoxanil 8% WP	2.0 gm/L of water
T ₂₆	Tricyclazole 60% + Bismethiazole 20% WP	0.6 gm/L of water
T ₂₇	Mancozeb 50% + Carbendazim 25% 75 WP	2.0 gm/L of water
T ₂₈	Carbendazim 50% WP	2.0 gm/L of water
T ₂₉	Tricyclazole 60% + Pyraclostrobin 15% WDG	2.0 gm/L of water
T ₃₀	Copper Oxchloride 50% WP	4.0 gm/L of water
T ₃₁	Tricyclazole 75% WP	2.0 gm/L of water
T ₃₂	Carbendazim 50% w/w WP	2.0 gm/L of water
T ₃₃	Hexaconazole 10% SC + Tricyclazole 20%	1.0 ml/L of water
T ₃₄	Tebuconazole 50% + Trifloxystrobin 20% WG	0.5 gm/L of water
T ₃₅	Azoxystrobin 20% + Difenconazole 12.5% SC	1.0 ml/L of water
T ₃₆	Control (Water spray only)	Water spray only

RESULTS AND DISCUSSION

Plant Characteristics

The plant characteristics of different mango trees are presented in Table 2. From this table it was observed that plant height of different treated Mango trees varied from 1.90 to 4.50 m where the highest plant height was recorded from treatment T₅ (4.50 m) and the lowest was in treatment T₁₉ (1.90 m). The base girth of different treated Mango trees ranged from 19 to 54 cm. The maximum base girth was obtained from treatment T₆ (54 cm) and the minimum in Treatment T₁₁ (19 cm).

Table 2. Plant characteristics of mango trees.

Treatments	Plant height (m)	Base girth (cm)	Canopy spread (m)		No. of primary branches	Tree volume (m ³)
			<i>N-S</i>	<i>E-W</i>		
T ₁	2.87	33.00	3.00	2.80	4.00	12.88
T ₂	2.30	38.00	2.10	3.14	3.00	8.43
T ₃	2.80	42.00	2.75	2.40	3.00	9.91
T ₄	4.10	50.00	3.40	4.20	4.00	31.60
T ₅	4.50	53.00	3.80	3.90	3.00	35.61
T ₆	4.00	54.00	3.70	3.76	2.00	29.71
T ₇	3.70	46.00	3.40	3.10	3.00	20.86
T ₈	2.52	41.00	2.90	3.10	3.00	12.11
T ₉	2.95	33.00	2.60	3.32	3.00	13.80
T ₁₀	1.95	20.00	1.70	2.00	4.00	3.56
T ₁₁	2.00	19.00	1.70	1.60	3.00	2.91
T ₁₂	3.00	22.00	1.70	1.80	4.00	4.90
T ₁₃	2.60	25.00	1.75	2.10	4.00	5.14
T ₁₄	2.15	22.00	1.61	1.67	5.00	3.09
T ₁₅	2.40	28.00	2.20	1.80	3.00	5.12
T ₁₆	2.43	31.00	2.55	2.52	4.00	8.34
T ₁₇	3.30	34.00	2.60	2.51	3.00	11.50
T ₁₈	2.80	30.00	2.30	3.10	3.00	10.90
T ₁₉	1.90	20.00	1.00	2.30	3.00	2.76
T ₂₀	3.00	38.00	3.00	3.10	2.00	14.90
T ₂₁	3.30	38.00	3.40	3.35	3.00	20.07
T ₂₂	3.10	37.00	2.20	2.30	6.00	8.38
T ₂₃	2.82	25.00	2.21	1.90	4.00	6.36
T ₂₄	2.70	22.00	1.80	1.60	2.00	4.17
T ₂₅	2.90	29.00	1.90	2.10	2.00	6.19
T ₂₆	3.50	38.00	2.10	3.00	3.00	12.15
T ₂₇	4.10	37.00	3.50	3.10	4.00	23.83
T ₂₈	3.60	42.00	3.70	3.90	5.00	27.75
T ₂₉	3.70	29.00	3.65	3.00	5.00	21.84
T ₃₀	3.20	32.00	2.90	3.10	4.00	15.37
T ₃₁	3.25	30.00	2.30	3.10	4.00	12.65
T ₃₂	4.30	31.00	4.20	3.60	5.00	34.91
T ₃₃	3.45	32.00	3.50	3.40	2.00	21.92
T ₃₄	3.70	35.00	3.40	2.90	3.00	19.60
T ₃₅	3.70	34.00	2.80	4.60	5.00	27.04
T ₃₆	3.10	28.00	2.45	2.20	4.00	8.95
Minimum	1.90	19.00	1.00	1.60	2.00	2.76
Maximum	4.50	54.00	4.20	4.60	6.00	35.61
Mean	3.10	33.28	2.66	2.82	3.53	14.42
Standard Dev.	0.67	8.94	0.78	0.77	1.00	9.63
±SE	0.11	1.49	0.13	0.13	0.17	1.61
CV (%)	21.72	26.85	29.21	27.32	28.34	66.80

The canopy spread (N-S & E-W) of different treated Mango trees varied from 1.00 to 4.20 m and 1.60 to 4.60 m, respectively. The highest canopy spread (N-S) was observed in treatment T₃₂ (4.20 m) and the lowest was in treatment T₁₉ (1.00 m). The highest canopy spread (E-W) was observed in treatment T₃₅ (4.60 m) and the lowest was in treatment T₂₄ (1.60 m). The number of primary branches of different treated Mango trees ranged from 2 to 6. The maximum primary branches were noted in treatment T₂₂ and minimum in treatments T₆, T₂₀, T₂₄, T₂₅, and T₃₂. The tree volume of different treated Mango trees varied from 2.76 to 35.61 m³. The maximum tree volume was obtained from treatment T₅ (35.61 m³) and the lowest was in treatment T₁₉ (2.76 m³). Number of primary branches and tree volume are directly proportional to the yield per plant.

Efficacy of Different New Fungicides on Disease Incidence, Disease Severity & Control of Anthracnose Disease and Yield & Yield Contributing Characters of Mango

The experiment's findings showed that fungicidal spray significantly reduced the incidence of anthracnose disease in mango. Most of the fungicides used in this study were able to perfectly prevent anthracnose, but they all decreased the disease's incidence and severity to varying degrees when compared to the control (Table 3).

Disease Incidence

Pre-harvest fungicidal spray had significant effect on anthracnose development in harvested mango fruits. All the fungicides included in this investigation reduced both the incidence and severity of anthracnose disease compared to control. But most of the fungicides were able to protect mango successfully from the disease (Table 3). The disease incidence varied from 0.67 to 80% (Figure 1). The lowest (0.67%) disease incidence was recorded in mango fruits harvested from the plants sprayed with T₁₀ treatment (Azoxystrobin 20% + Difenconazole 12.5% SC) followed by T₁₁ treatment (Carbendazim 50% WDG) (0.77%), T₁ treatment (Trifloxystrobin 25% + Tebuconazole 50% WDG) (0.80%), T₃₁ treatment (Tricyclazole 75% WP) (0.80%), T₃ treatment (Tebuconazole 50% + Trifloxystrobin 25% WDG) (0.83%) and T₂ treatment (Carbendazim 50% WDG) (0.88%). Other fungicides also showed significant effect in controlling the incidence of the disease. The highest (80%) disease incidence was recorded in the control treatment followed by mango fruits from the plants sprayed with the T₃₂ treatment (Carbendazim 50% w/w WP) (25.08%), T₃₀ treatment (Copper Oxychloride 50% WP) (23.33%), T₂₀ treatment (Mancozeb 80% WP) (18.33%), T₂₁ treatment (Propineb 70% + Dimethomorph 10% WP) (18.29%) and T₂₃ treatment (Hexaconazole 10% SC) (16.20%) (Table 3).

Disease Severity

According to field evaluation studies, two consecutive sprays of different new fungicides on 30.03.2024 and 12.05.2024 and continued up to the harvest of the fruit at 15 days interval at 15 days interval, beginning from the onset of the disease along with one spray of insecticide on 02.04.2024 (Imidacloprid group), were found to be the most effective in reducing the disease severity up to 2% compared to 80% in the unsprayed control treatment (Figure 2). In case of disease severity, the lowest disease severity (2%) disease severity was recorded in treatments sprayed with T₁= Trifloxystrobin 25% + Tebuconazole 50% WDG, T₃=Tebuconazole 50% + Trifloxystrobin 25% WDG, T₁₀= Azoxystrobin 20% + Difenconazole 12.5% SC, T₁₁= Carbendazim 50% WDG and T₃₁= Tricyclazole 75% WP followed by 2.50% in T₂= Carbendazim 50% WDG, T₂₇= Mancozeb 50% + Carbendazim 25% 75 WP & T₃₅= Azoxystrobin 20% + Difenconazole 12.5% SC; 2.6% in T₄= Azoxystrobin 20% + Difenconazole 12.5% SC, 3% in T₅= Carbendazim 50% WDG, & T₁₉= Pyraclostrobin 25% SC, whereas the highest disease severity (80%) was recorded in the unsprayed control treatment followed by T₂₃= Hexaconazole 10% SC (36%), T₃₀= Copper Oxychloride 50% WP (35%), T₂₁= Propineb 70% + Dimethomorph 10% WP & T₃₂= Carbendazim 50% w/w WP (32%), T₂₀= Mancozeb 80% WP (22%) and T₃₂= Carbendazim 50% w/w WP (12%). The highest disease incidence as well as the disease severity of mango was always noted from unsprayed control plants. According to the findings, each new fungicide that was tested was successful in lowering the severity of the disease and increasing fruit yield compared to the unsprayed control.

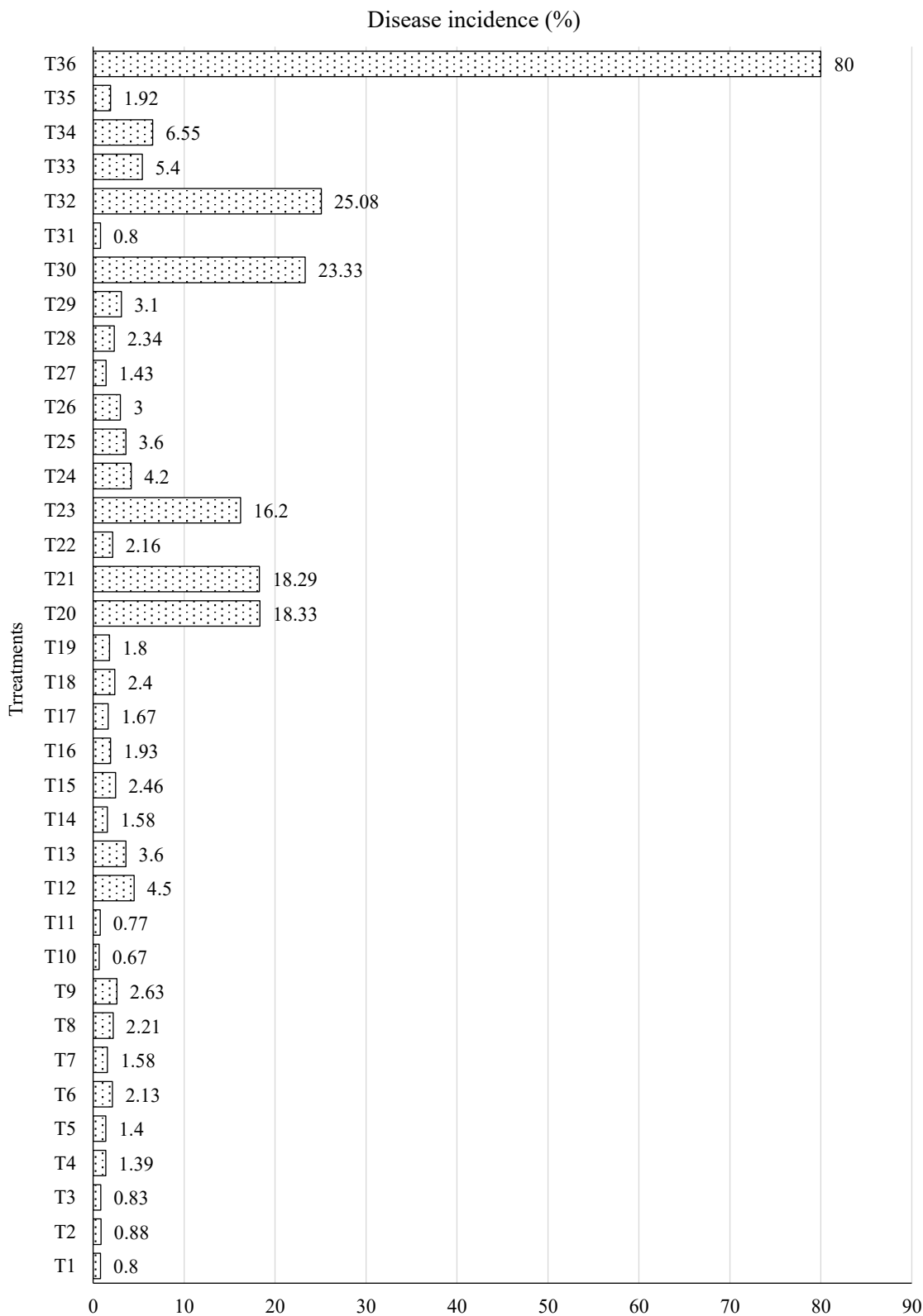


Figure 1. Disease incidence (%) of different new fungicides against anthracnose of mango at field level.

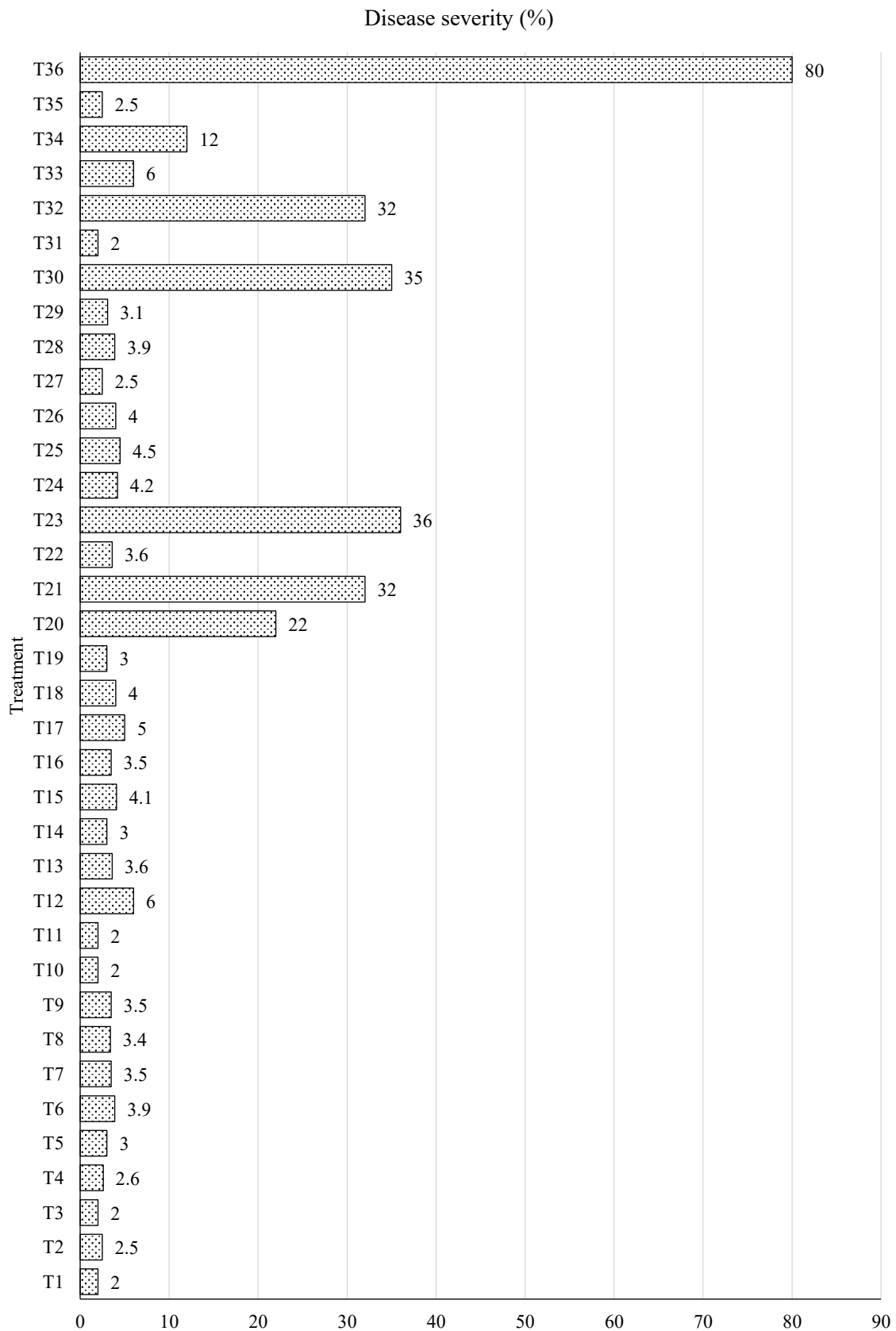


Figure 2. Disease Severity (%) of different new fungicides against anthracnose of mango at field level.

Efficacy of Different New Fungicides

Different new fungicides showed differential efficacy to control the anthracnose disease of mango (Figure 3). The probable cause might be the amounts of ingredient used in each fungicide during formulation were different as each of them was obtained from different sources.

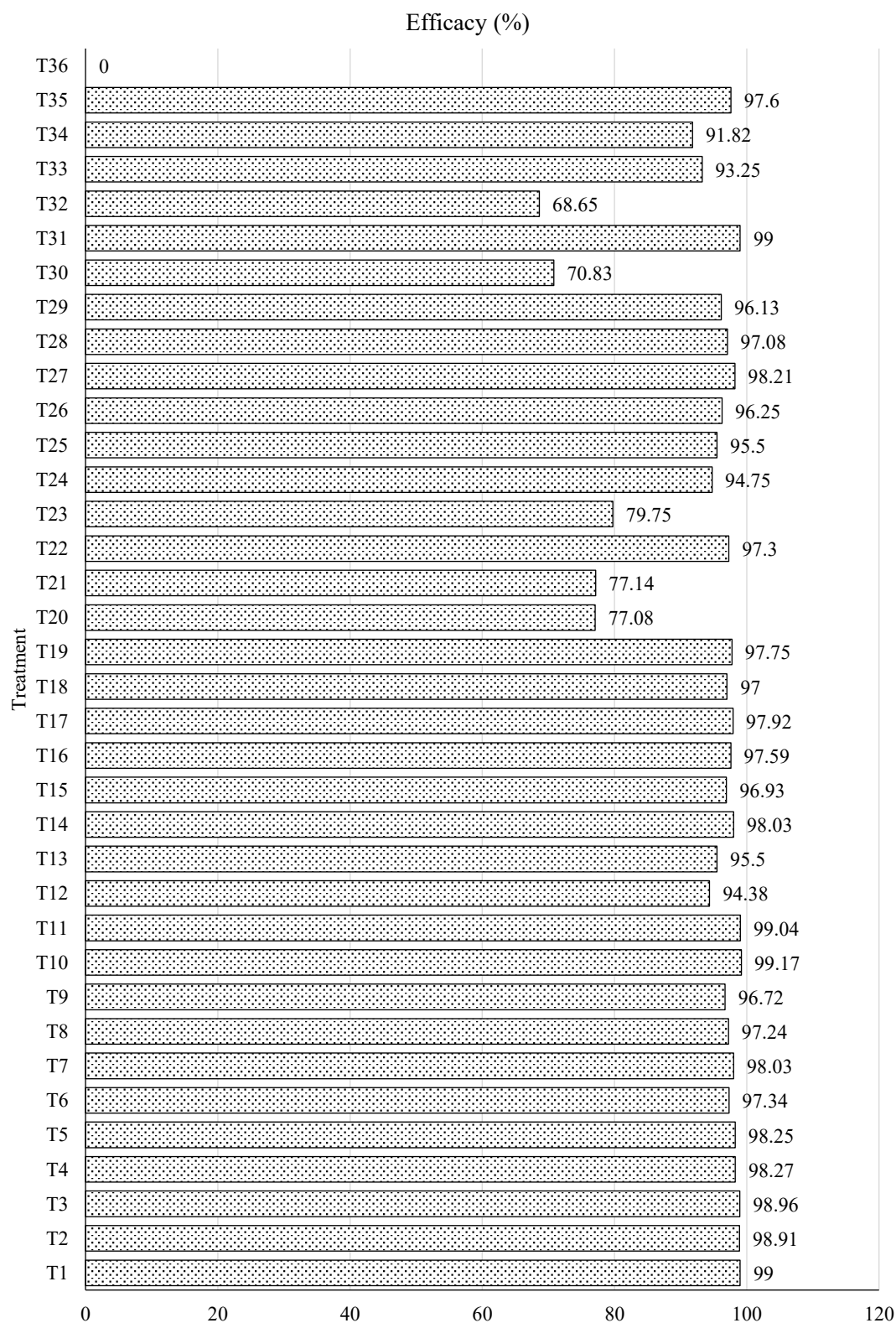


Figure 3. Efficacy (%) of different new fungicides against anthracnose of mango at field level.

Efficacy of different new fungicides ranged from 68.65 to 99.17%. Thirty (30) new fungicides suppressed the disease >90%. On the other hand, only five (5) new fungicides controlled the disease <80%. The lowest efficacy (68.65%) was noted in T₃₂= Carbendazim 50% w/w WP treatment and the highest efficacy (99.17%) in T₁₀= Azoxystrobin 20% + Difenconazole 12.5% SC treatment. In respect of efficacy of different new fungicides, the better fungicidal treatments are prescribed from higher to lower efficacy as: T₁₀= Azoxystrobin 20% + Difenconazole 12.5% SC (99.17%) > T₁₁= Carbendazim 50% WDG (99.04%) > T₁= Trifloxystrobin 25% + Tebuconazole 50% WDG (99%) & T₃₁= Tricyclazole 75% WP (99%) > T₃= Tebuconazole 50% + Trifloxystrobin 25% WDG (98.96%) > T₂= Carbendazim 50% WDG (98.91%) > T₄= Azoxystrobin 20% + Difenconazole 12.5% SC (98.27%) > T₅= Carbendazim 50% WDG (98.25%) > T₂₇= Mancozeb 50% + Carbendazim 25% 75 WP (98.21%) > T₇= Difenconazole 12.5% + Azoxystrobin 20% SC (98.03%) & T₁₄= Azoxystrobin 20% + Difenconazole 12.5% SC (98.03%). Field performance of some new fungicides with control treatment in controlling Anthracnose disease of Mango are presented in **Figure 5**.

Because of the inherent characteristics of the molecule, trifloxystrobin + tebuconazole proved to be the most efficient fungicides. Tebuconazole is a triazole fungicide that prevents the demethylation stage of the fungal cell wall's sterol production. It offers consistent effectiveness over a few weeks because it is both curative and protective. Trifloxystrobin is an oximinoacetate mesostemic fungicide that is readily absorbed by the plant's waxy layers and redistributed by the surface, helping to control disease in almost untreated plant tissues. Additionally, it prevents the formation of appressorium, germ tube expansion, and fungal spore germination. According to Sundravadana *et al.* (2007) [15], applying azoxystrobin at concentrations of 1, 2, and 4 ml/l considerably inhibited the growth of both panicle and leaf anthracnose in field conditions.

Mango pre-harvest anthracnose symptoms were successfully treated with tricyclazole, carbendazim, hexaconazole, and benomyl (0.1%) Venkataravanappa *et al.* (2008) [16]. The best way to manage the foliar anthracnose of mango cv. Dashehari was to apply three consecutive sprays of carbendazim + mancozeb at 10-day intervals beginning with the onset of disease symptoms Kumar (2014) [17]. Additionally, the efficiency of combi-products (systemic and non-systemic) can be explained by the fact that either or both of their ingredients are excellent fungicides with post-infection action to prevent mycelial growth and sporulation as well as curative and eradication properties.

Number of Fruits Per Plant

The effect of different new fungicides on number of fruits per plant are presented in Table 3. The number of fruits per plant ranged from 17 to 204. Among the fungicides studied, the highest number of fruits per plant (204) was observed in the treatment T₉ (Azoxystrobin 20% + Difenconazole 12.5% SC) whereas the lowest number of fruits per plant (17) was recorded in the treatments T₂₀ (Mancozeb 80% WP), T₂₁ (Propineb 70% + Dimethomorph 10% WP) and T₂₆ (Tricyclazole 60% + Bismethiazole 20% WP). The number of fruits per plant is significantly and negatively correlated with the disease severity ($y = -1.2854x + 80.783$, $R^2 = 0.157$) (Figure 6). High disease severity decreases the number of fruits per plant ultimately lowers fruit yield per plant.

Individual Fruit Weight

Table 3 shows the consequences of different new fungicides on the weight of individual fruit. Individual fruit weight ranged from 123 to 626 g. Among the fungicides, the highest individual fruit weight (626 g) was observed in the treatment T₂₆ (Tricyclazole 60% + Bismethiazole 20% WP) whereas the lowest individual fruit weight (123) was recorded in the treatments T₁₀ (Azoxystrobin 20% + Difenconazole 12.5% SC). The variation in individual fruit weight is due to the different varieties, age and tree volume of mango. High individual fruit weight and the number of fruits per plant proportionately increase fruit yield per plant.

Table 3. Efficacy of different new fungicides on disease incidence, disease severity & control of anthracnose disease and yield & yield contributing characters of mango.

Treatments	Disease incidence (%)	Disease severity (%)	Efficacy (%)	Number of fruits/plant	Individual fruit wt. (g)	Yield (kg/plant)
T ₁	0.80	2.00	99.00	193.50	178.80	34.60
T ₂	0.88	2.50	98.91	139.50	139.20	19.42
T ₃	0.83	2.00	98.96	172.00	148.80	25.59
T ₄	1.39	2.60	98.27	97.50	397.00	38.71
T ₅	1.40	3.00	98.25	86.50	410.60	35.52
T ₆	2.13	3.90	97.34	62.50	370.80	23.18
T ₇	1.58	3.50	98.03	106.00	370.60	39.28
T ₈	2.21	3.40	97.24	152.00	124.00	18.85
T ₉	2.63	3.50	96.72	204.00	134.00	27.34
T ₁₀	0.67	2.00	99.17	80.00	123.80	9.90
T ₁₁	0.77	2.00	99.04	73.00	148.00	10.80
T ₁₂	4.50	6.00	94.38	35.00	281.00	9.84
T ₁₃	3.60	3.60	95.50	33.50	316.50	10.60
T ₁₄	1.58	3.00	98.03	35.50	264.60	9.39
T ₁₅	2.46	4.10	96.93	34.00	352.00	11.97
T ₁₆	1.93	3.50	97.59	82.50	280.80	23.17
T ₁₇	1.67	5.00	97.92	106.00	276.00	29.26
T ₁₈	2.40	4.00	97.00	80.50	245.60	19.77
T ₁₉	1.80	3.00	97.75	42.00	241.60	10.15
T ₂₀	18.33	22.00	77.08	17.00	212.00	3.60
T ₂₁	18.29	32.00	77.14	17.00	198.00	3.37
T ₂₂	2.16	3.60	97.30	45.50	222.80	10.14
T ₂₃	16.20	36.00	79.75	20.00	206.00	4.12
T ₂₄	4.20	4.20	94.75	18.50	590.60	10.93
T ₂₅	3.60	4.50	95.50	21.50	579.20	12.45
T ₂₆	3.00	4.00	96.25	17.00	626.00	10.64
T ₂₇	1.43	2.50	98.21	75.00	146.40	10.98
T ₂₈	2.34	3.90	97.08	50.50	157.20	7.94
T ₂₉	3.10	3.10	96.13	63.00	159.20	10.03
T ₃₀	23.33	35.00	70.83	19.50	236.00	4.60
T ₃₁	0.80	2.00	99.00	88.50	136.00	12.04
T ₃₂	25.08	32.00	68.65	25.50	245.00	6.25
T ₃₃	5.40	6.00	93.25	52.50	201.80	10.59
T ₃₄	6.55	12.00	91.82	51.50	202.00	10.40
T ₃₅	1.92	2.50	97.60	40.50	248.60	10.07
T ₃₆	80.00	80.00	0.00	22.50	198.00	4.46
Minimum	0.67	2.00	0.00	17.00	123.80	3.37
Maximum	80.00	80.00	99.17	204.00	626.00	39.28
Mean	6.97	9.66	91.29	68.36	260.24	15.28
Standard Dev.	14.12	15.68	17.65	50.87	130.32	10.25
±SE	2.35	2.61	2.94	8.48	21.72	1.71
CV (%)	202.58	162.26	19.33	74.42	50.08	67.09

Fruit Yield

Table 3 displays the effects of various new fungicides on fruit production. Fruit yield (kg/plant) varied from 3.37 to 39.28 kg (Figure 4). Among the fungicides, the highest fruit yield (39.28 kg/plant) was detected in the treatment T₇ (Difenoconazole 12.5% + Azoxystrobin 20% SC) followed by treatment T₄= Azoxystrobin 20% + Difenoconazole 12.5% SC (38.71 kg), T₅= Carbendazim 50% WDG (35.52 kg) whereas the lowest fruit yield per plant (3.37 kg) was recorded in the treatments T₂₁ (Propineb 70% + Dimethomorph 10% WP). The variation in individual fruit weight is due to the different varieties, age and tree volume of mango. High individual fruit weight and the number of fruits per plant proportionately increase fruit yield per plant. The fruit yield per plant is significantly and negatively correlated with the disease severity ($y = -0.2832x + 18.013$, $R^2 = 0.1878$) (Figure 6). High disease severity decreases fruit yield per plant drastically.

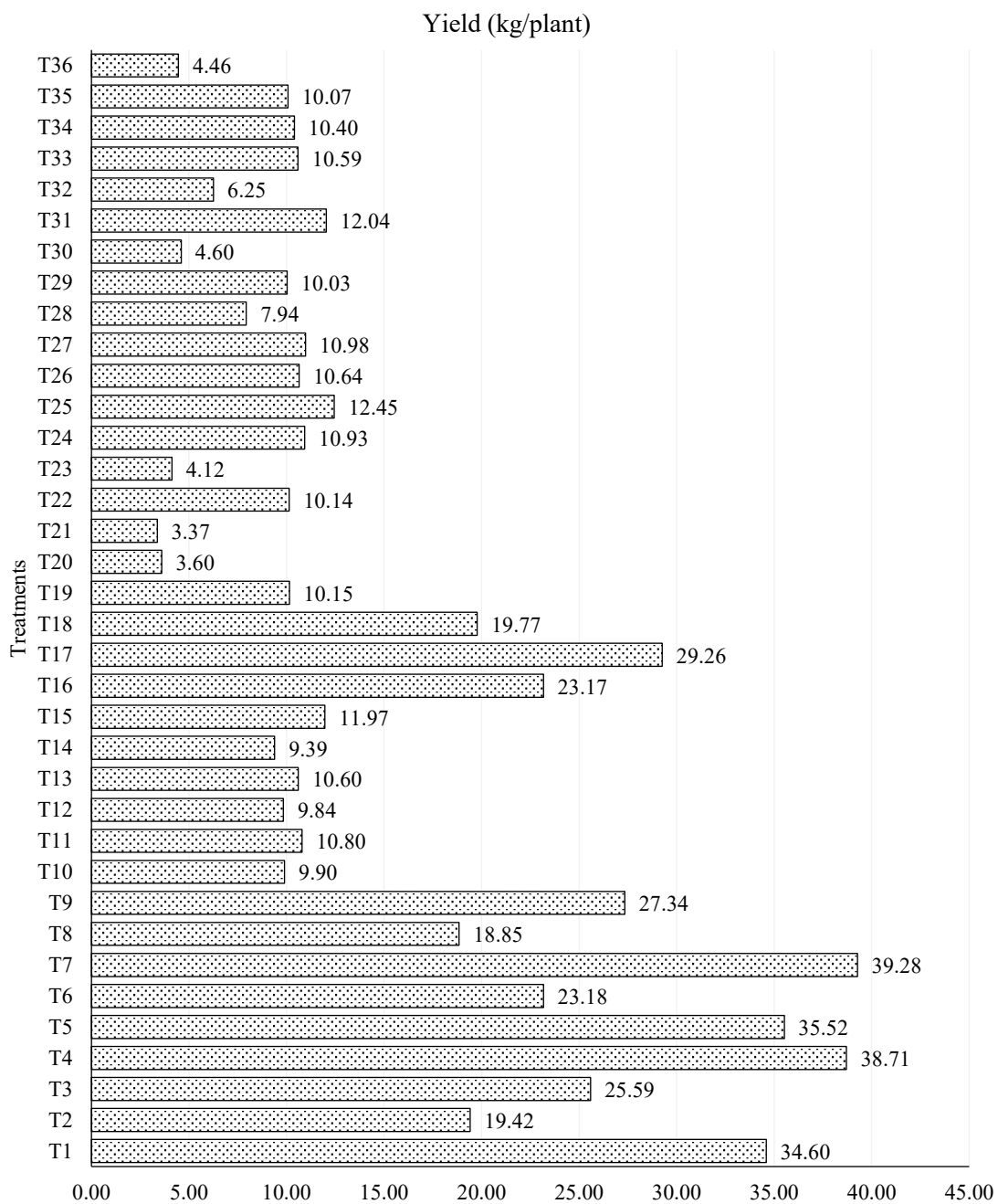


Figure 4. Effect of different new fungicides against anthracnose of mango on yield parameters.

Quantitative and Qualitative Fruit Characteristics of Mango

The consequences of different new fungicides on quantitative and qualitative fruit characteristics of Mango are displayed in Table 4.

Table 4. Quantitative and qualitative fruit characteristics of mango.

Treatments	Fruit length (cm)	Fruit breadth (cm)	Wt. of peel (g)	Thickness of pulp (cm)	Wt. of stone (g)	Stone length (cm)	Stone breadth (cm)	Stone thickness (cm)	TSS (%)	Edible portion (%)
T ₁	8.30	5.92	28.00	0.13	30.34	6.84	3.30	2.37	17.00	67.37
T ₂	8.58	5.62	28.67	0.13	29.34	7.86	3.24	2.30	17.00	58.33
T ₃	8.88	6.18	30.67	0.10	31.00	7.17	3.16	2.26	18.00	58.56
T ₄	11.94	8.12	44.67	0.27	40.34	8.94	3.97	2.20	17.00	78.59
T ₅	12.46	7.88	49.67	0.16	50.00	9.90	4.17	1.97	19.00	75.73
T ₆	11.64	7.78	51.00	0.10	36.00	7.54	4.47	2.50	16.50	76.54
T ₇	11.90	7.70	49.00	0.10	37.00	7.23	3.99	2.34	17.00	76.79
T ₈	8.46	5.58	28.67	0.10	29.34	7.53	3.37	2.24	18.00	53.22
T ₉	8.50	5.68	31.00	0.10	29.00	6.93	3.53	2.53	18.00	55.22
T ₁₀	8.26	5.40	29.34	0.36	28.34	7.20	3.10	2.36	20.00	53.41
T ₁₁	8.20	7.06	28.00	0.13	40.00	7.16	3.30	2.20	17.00	54.05
T ₁₂	10.98	7.20	54.00	0.16	47.67	6.26	4.43	2.20	15.00	63.82
T ₁₃	10.95	7.80	48.00	0.10	35.00	8.15	1.25	1.50	17.50	73.78
T ₁₄	7.98	7.84	48.34	0.10	40.00	7.87	5.45	2.00	16.00	66.61
T ₁₅	9.34	8.86	48.67	0.10	48.67	6.67	4.70	2.00	15.20	72.35
T ₁₆	8.62	8.46	47.34	0.36	40.34	8.47	4.53	2.23	16.00	68.77
T ₁₇	13.76	6.42	50.00	0.36	26.67	11.23	3.43	1.67	15.00	72.22
T ₁₈	13.00	5.94	53.67	0.10	25.34	12.23	3.60	1.23	14.50	67.83
T ₁₉	13.68	5.82	47.34	0.36	22.67	11.70	3.16	1.02	15.50	71.02
T ₂₀	12.04	5.14	34.00	0.13	21.69	10.30	3.09	1.15	16.00	73.73
T ₂₁	9.00	5.17	37.00	0.15	20.22	9.68	3.02	1.18	18.00	71.10
T ₂₂	8.92	5.98	32.34	0.10	33.00	7.84	4.67	2.36	17.00	70.67
T ₂₃	10.81	5.00	28.76	0.11	31.60	6.49	3.79	1.88	16.00	70.70
T ₂₄	16.64	8.52	68.00	0.30	58.66	11.74	4.67	2.40	16.00	78.55
T ₂₅	14.40	8.76	72.67	0.10	61.34	11.73	4.37	2.40	16.00	76.86
T ₂₆	16.74	8.64	59.00	0.10	55.67	11.24	4.54	2.30	16.50	81.68
T ₂₇	7.76	5.52	36.67	0.10	24.00	5.73	2.84	2.30	16.00	58.56
T ₂₈	12.88	5.52	37.00	0.10	28.00	5.80	2.86	2.40	15.00	58.65
T ₂₉	8.06	6.04	37.34	0.10	25.34	7.13	2.40	2.40	17.00	60.63
T ₃₀	8.28	5.98	36.00	0.12	31.20	6.19	2.55	2.18	16.50	71.53
T ₃₁	8.44	5.38	34.34	0.36	44.34	6.77	5.20	2.23	17.00	42.15
T ₃₂	9.00	5.66	33.50	0.11	29.80	6.56	2.17	2.14	18.00	74.16
T ₃₃	9.00	6.34	49.00	0.16	31.64	9.10	7.20	2.26	18.00	60.04
T ₃₄	9.40	6.45	36.50	0.15	33.50	7.85	4.90	2.20	18.00	65.35
T ₃₅	10.13	6.67	47.66	0.16	43.50	7.40	3.56	2.60	15.00	63.33
T ₃₆	9.32	7.38	41.00	0.16	30.34	7.10	3.20	2.30	17.00	63.97
Minimum	7.76	5.00	28.00	0.10	20.22	5.73	1.25	1.02	14.50	42.15
Maximum	16.74	8.86	72.67	0.36	61.34	12.23	7.20	2.60	20.00	81.68
Mean	10.45	6.65	42.13	0.16	35.30	8.21	3.76	2.11	16.73	66.83
Standard Dev.	2.46	1.20	11.33	0.09	10.38	1.89	1.08	0.41	1.23	9.00
±SE	0.41	0.20	1.89	0.02	1.73	0.31	0.18	0.07	0.21	1.50
CV (%)	23.55	18.03	26.89	56.78	29.40	22.96	28.73	19.39	7.36	13.47

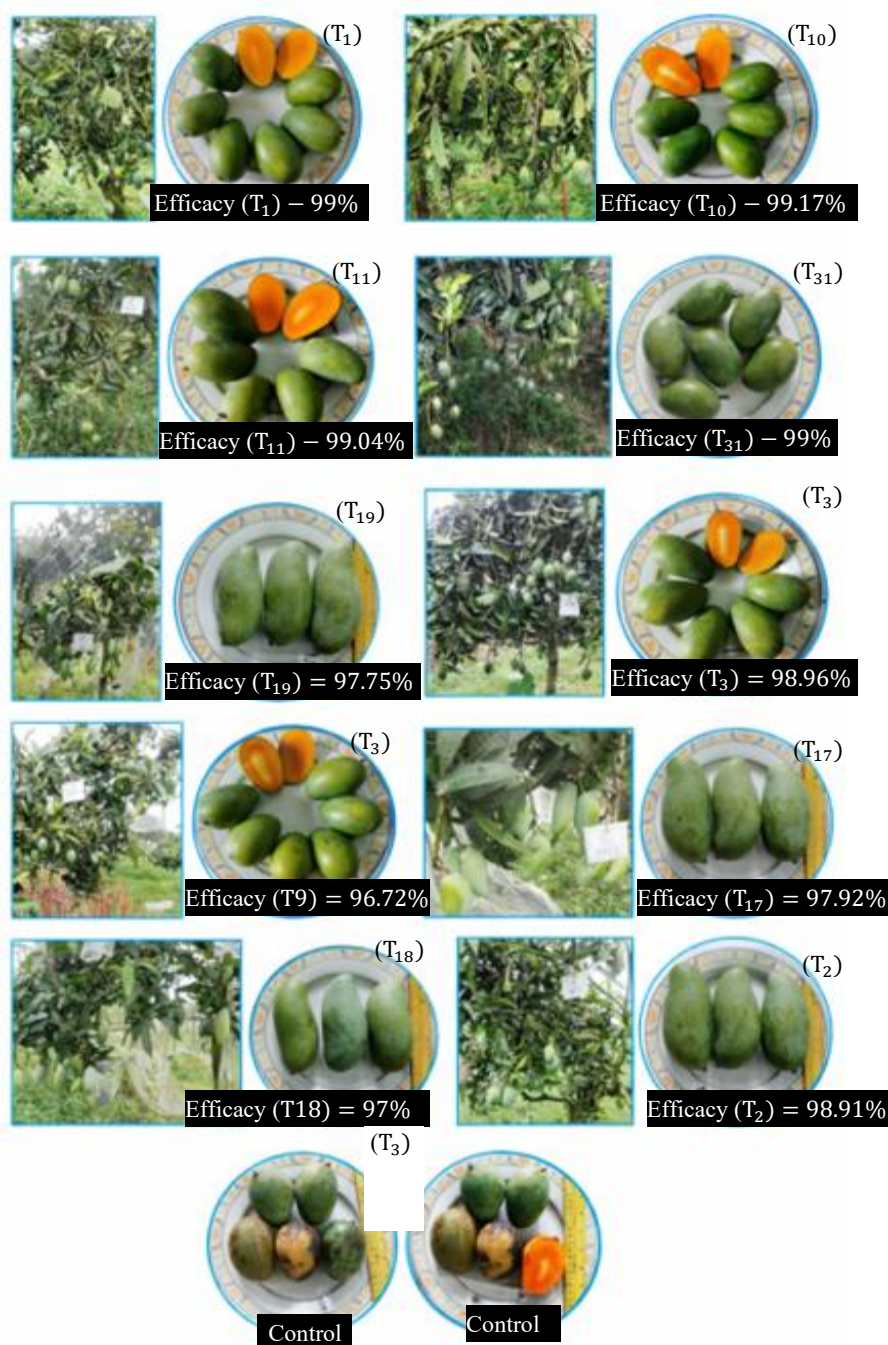


Figure 5. Filed performance of some new fungicides with control treatment in controlling anthracnose disease of mango.

Among quantitative characteristics, fruit length varied from 7.76 to 16.74 cm. The highest fruit length (16.74 cm) was noted in treatment T₂₄=Tricyclazole 20% + Hexaconazole 10% SC and the lowest fruit length (7.76 cm) in treatment T₂₇= Mancozeb 50% + Carbendazim 25% 75 WP. Fruit breadth varied from 5 to 8.86 cm. The highest fruit breadth (8.86 cm) was noted in treatment T₁₅= Mancozeb 64% + Cymoxanil 8% WP and the lowest fruit breadth (5 cm) in treatment T₂₃= Hexaconazole 10% SC. Weight of pulp varied from 28 to 72.67 g. The highest weight of pulp (72.67 g) was noted in treatment T₂₅= Mancozeb 64% + Cymoxanil 8% WP and the lowest weight of pulp (28 g) in treatment T₁₁= Carbendazim 50% WDG.

Thickness of pulp varied from 0.1 to 0.36 cm. The highest thickness of pulp (0.36 cm) was noted in treatments T₁₆= Azoxystrobin 20% + Tebuconazole 15% SC & T₁₇= Mancozeb 80% WP and the lowest thickness of pulp (0.1 cm) was noted in 15 fungicidal treatments.

Weight of stone varied from 20.22 to 61.34 g. The highest weight of stone (61.34 g) was documented in treatment T₂₅= Mancozeb 64% + Cymoxanil 8% WP and the lowest weight of stone (20.22 g) in treatment T₂₁= Propineb 70% + Dimethomorph 10% WP. Stone length varied from 5.73 to 12.23 cm. The highest fruit length (12.23 cm) was noted in treatment T₁₈= Mancozeb 80% WP and the lowest stone length (5.73 cm) in treatment T₂₇= Mancozeb 50% + Carbendazim 25% 75 WP. Stone breadth varied from 1.25 to 7.20 cm. The highest stone breadth (7.20 cm) was stated in treatment T₃₃= Hexaconazole 10% SC + Tricyclazole 20% and the lowest stone breadth (1.25 cm) in treatment T₁₃= Copper Hydroxide 77% WP. Stone thickness differed from 1.02 to 2.60 cm.

The highest stone thickness (2.60 cm) was noted in treatments T₃₅= Azoxystrobin 20% + Difenconazole 12.5% SC and the lowest stone thickness (1.02 cm) in treatment T₁₉= Pyraclostrobin 25% SC. Total Soluble Solids (TSS) and edible portion are influenced by the application of different new fungicides. Percentage of Total Soluble Solids (TSS) differed from 14.50 to 20. The highest TSS (20%) was recorded in the treatment T₁₀= Azoxystrobin 20% + Difenconazole 12.5% SC whereas the lowest TSS (14.50%) observed in the treatment T₁₈= Mancozeb 80% WP. Among new fungicidal treatments, edible portion varied from 42.15 to 81.68%.

The highest edible portion (81.68%) was recorded in treatment T₂₆= Tricyclazole 60% + Bismethiazole 20% WP followed by the treatments T₄= Azoxystrobin 20% + Difenconazole 12.5% SC (78.59%), T₇= Difenconazole 12.5% + Azoxystrobin 20% SC (76.79%), T₆= Tricyclazole 75% WP (76.54%), T₅= Carbendazim 50% WDG (75.73%) whereas the lowest edible portion (42.15%) observed in the treatment T₃₁= Tricyclazole 75% WP. There is a significant & strong positive correlation between edible portion and individual fruit weight ($y=0.0538x+52.828$, $R^2=0.6067$). With the increase of individual fruit weight proportionately increased the edible portion.

CORRELATION STUDIED OF IMPORTANT PARAMETERS OF THE RESEARCH

The results of the study showed that there endured a substantial negative & positive correlation of disease severity (%) with disease incidence (%), efficacy of different new fungicides (%), number of fruits per plant and fruit yield (kg/plant) of mango (Figure 6). High significant positive correlations were found to exist among the anthracnose disease severity (%) with disease incidence (%) ($y= 0.8705x + 1.4419$, $R^2=0.9344$). On the other hand, strong significant negative correlations were found to exist among anthracnose disease severity (%) with efficacy of different new fungicides (%) ($y= -1.0881x + 101.8$, $R^2=0.9344$), number of fruits per plant ($y= -1.2854x+80.783$, $R^2=0.157$) and fruit yield (kg/plant) ($y = -0.2832x+18.013$, $R^2=0.1878$). The outcomes supported the idea that the use of chemical fungicides would reduce the severity of anthracnose disease and thereby increased yield contributing characters as well as the fruit yield of mango. There is a substantial & positive correlation between fruit yield (kg/plant) & tree volume ($y= 0.2896x + 11.1$, $R^2=0.0741$). The plants with higher tree volume produce higher fruit yield. Moreover, there is a strong & positive correlation between individual fruit weight (g) and edible portion (%) ($y = 0.0538x + 52.828$, $R^2=0.6067$). Usually, higher individual fruit weight possesses more edible portions as compared to lower individual fruit weight.

CONCLUSION

It may be concluded from this study that fungicidal spray had significant effect on anthracnose development in mango. All the fungicides included in this investigation reduced both the incidence and severity of anthracnose at different levels compared to control but most of them were able to protect mango successfully from the disease. Out of thirty-five (35) fungicides, thirty (30) fungicides suppressed the disease by more than 90%. On the other hand, only five (5) fungicides suppressed the disease by less than 80%.

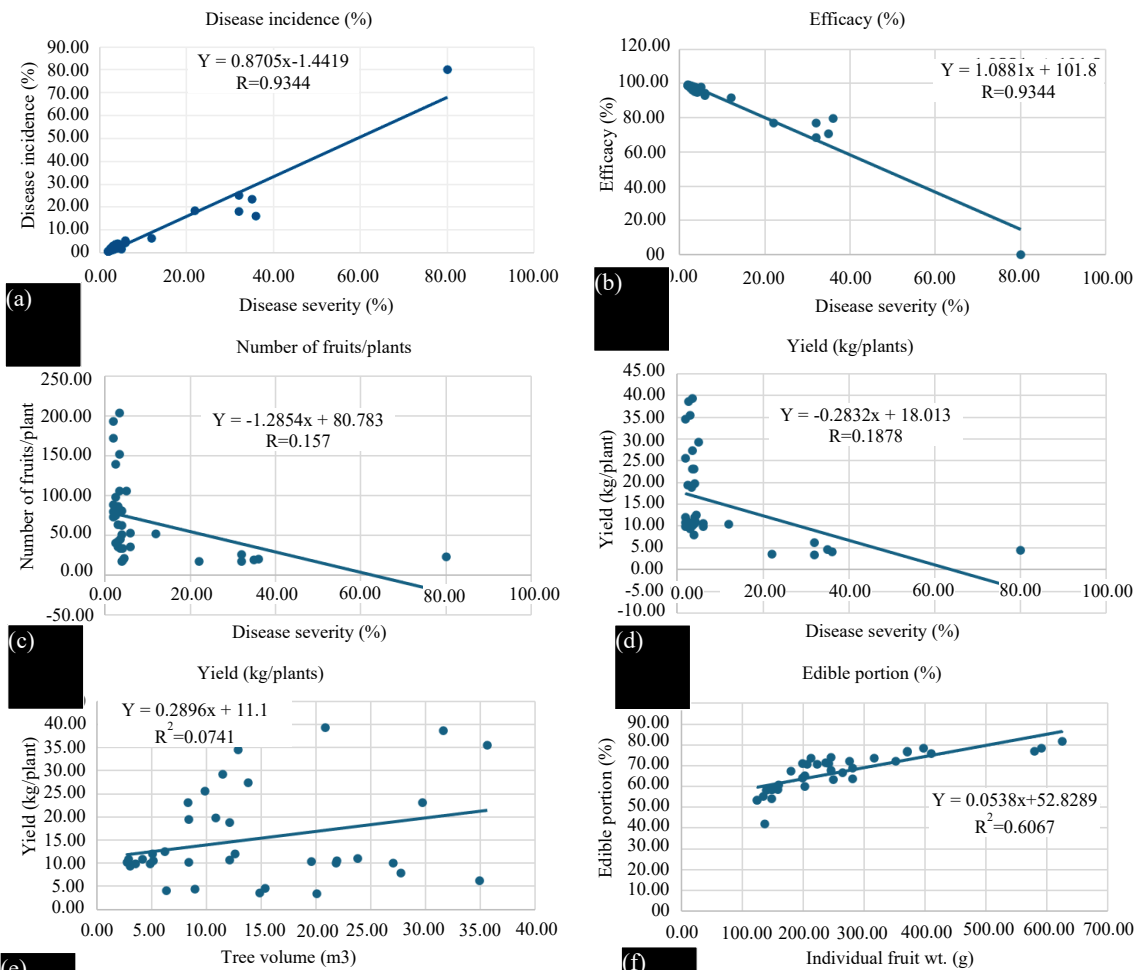


Figure 6. Correlation of disease severity (%) with disease incidence (%), efficacy (%), number of fruits/plant, fruit yield (kg/plant); fruit yield (kg/plant) vs tree volume and individual fruit weight (g) vs edible portion (%) of mango (a-f).

In respect of efficacy of different new fungicides, the effective fungicidal treatments are prescribed from higher to lower efficacy as: Azoxystrobin 20% + Difenoconazole 12.5% SC > Carbendazim 50% WDG > Trifloxystrobin 25% + Tebuconazole 50% WDG > Tricyclazole 75% WP > Mancozeb 50% + Carbendazim 25% 75 WP. Most of the fungicides under investigation were able to control the disease successfully. The study showed that fungicides that controlled the disease produced higher fruit harvests and, consequently, the highest financial returns. The most effective spray over control was Azoxystrobin 20% + Difenoconazole 12.5% SC, which was followed by Carbendazim 50% WDG and Trifloxystrobin 25% + Tebuconazole 50% WDG. The results showed that using fungicides to control mango anthracnose had a beneficial return. The mango growers found that spraying Azoxystrobin 20% + Difenoconazole 12.5% SC, Carbendazim 50% WDG and Trifloxystrobin 25% + Tebuconazole 50% WDG are the most efficient way to control mango anthracnose and ensure successful mango cultivation.

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