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Research Article

Mulberry Varieties Evaluation for Foliar Diseases in Bangladesh

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ABSTRACT

Common mulberry disease is occurring in Bangladesh due to the development of new varieties and climate changes. That's why this study was undertaken to quantify the incidence of common mulberry disease under various cropping seasons in Bangladsesh. Three common mulberry diseases, viz., powdery mildew (*Phyllactinia corylea*), leaf spot (*Pseudocercospora mori*) and tukra (*Meconellicoccus hirsutus*) were studied for their occurrence in twelve mulberry varieties, namely, Black, BM-1, BM-3, BM-4, BM-5, BM-6, BM-7, BM-8, BM-10, BM-11, S-13 and S-30 during three crop seasons viz., summer (April-June), late autumn (October-December) and rainy season (June-August) in Bangladesh. Among the three disease and three cropping seasons, the infestation of powdery mildew disease in late autumn season was comparatively high and the infestation of tukra (mealy bug) disease was comparatively low almost all the three seasons. The BM-11, BM-8, and Black varieties to powdery mildew, BM-4, BM-11 to leaf spot and BM-8, BM-10, BM-11 and S-30 were comparatively resistant to tukra disease. This study demonstrated that late autumn season was comparatively more susceptible than other seasons for all the three diseases. It may be due to the favorable climatic conditions the infestation of foliar diseases were high in late autumn season. Genetical like anatomical and structural characteristics of various varieties viz. BM-11, Black, BM-4, BM-8, BM-10 and S-30 were more resistant to foliar diseases.

Key words: Powdery mildew, leaf spot, tukra, *Phyllactinia corylea, Pseudocercospora mori Meconellicoccus hirsutus*

INTRODUCTION

Mulberry (*Morus* sp.) is a hardy deciduous perennial tree or shrub used as a food source for the domesticated silkworm, *Bombyx mori* (Aggarwal *et al.,* 2004). The most important factor is the mulberry leaf, contributing about 38.2% followed by climate (37.0%), rearing techniques (9.3%), silkworm race (4.2%), silkworm egg (3.1%) and other factors (8.2%) in producing good quality cocoons (Miyashata, 1986). Hence, quality of mulberry leaf is one of the basic prerequisite of sericulture and plays a pivotal role for successful silkworm cocoon crop (Guttierrez *et al.*, 1997). It has been estimated that, nearly 70% of the silk proteins are derived from mulberry leaves. Hence, silkworms should be fed with good quality mulberry leaves in abundant quantity for the successful cocoon production (Vijaya *et al.*, 2009). However, diseases are some of the limiting factors for successful mulberry cultivation. Because, like other plant mulberry is affected by a number of diseases caused by fungi, bacteria, viruses and nematodes (Sengupta *et al.*, 1990; Yashihiko, 1995).

Common mulberry diseases in Bangladesh are powdery mildew, leaf spot and tukra (Rabbel, 1995). Powdery mildew is one of the major foliar fungal diseases caused by *Phyllactinia corylea* (Pers). Karst which is also known as *P. moricola* (P. Henn.) Homma (Takamatsu *et al.*, 1982). Several studies found that the loss due to mildew is around 12% besides causing depletion in nutritive value (Teotia and Sen, 1994; Qadri *et al.*, 1998). Likewise, the highest leaf infection of 56-70% resulted in 29-41% of disease severity in mulberry in Bangladesh (Rabbel, 1995). Sharma et al. (2009) found through leaf spot disease causes 10-12% leaf yield loss. Rabbel (1995) also observed that leaf infection was 44-55% with 17-21% disease severity in Bangladesh through the leaf spot disease. Likewise, the symptoms of mealy bug infestation in mulberry collectively called as tukra (Misra, 1919). The tukra (mealy bug) disease affected mulberry plantation three to six tones of leaf yield/ha/ year recorded by (Kumar *et al*., 1992).

Our previous study showed that the infestation of powdery mildew disease was comparatively high in spring

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season than the autumn season and S-30 mulberry variety in autumn and black variety in spring season were comparatively more tolerant to powdery mildew disease (Faruque *et al.,* 2016). However, no study was undertaken to evaluate the susceptibility of common mulberry disease with respect to seasons. Therefore, the present study was undertaken to find out the highest severity period among the three different crop seasons and suitable mulberry variety among the twelve different varieties *viz*. Black, BM-1, BM-3, BM-4, BM-5, BM-6, BM-7, BM-8, BM-10, BM-11, S-13 and S-30 for changing agro-climatic conditions of Bangladesh to minimize the crop loss due to the incidence of powdery mildew, leaf spot and tukra diseases. It was hypothesized that infestation of powdery mildew, leaf spot and tukra diseases will be varied irrespective to mulberry varieties and crop seasons.

MATERIALS AND METHODS

Experimental duration and location

This study was conducted for two years in three crop season's each year like, late autumn, summer and rainy season under the mulberry garden, Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh. The two years average data were used for this study.

Basic soil physical and chemical properties

The soils of the experimental plots of BSRTI were mainly loam in nature, having normally alkaline characteristics with pH ranging from 7.2 to 7.6. As a consequence of this alkalinity, the soil is poor in potassium and available phosphorus. Both carbon and nitrogen levels are low in uncultivated as well as in the cultivated plots. Nitrogen level is not in balanced with carbon. This is more prominent in the farm areas where mulberry is cultivated for years. Toxic metals are present in traces but they are well below the harmful levels (BSR, 1991). The basic physical and chemical properties of soil were shown in (Table 1).

Mulberry varieties

Twelve mulberry varieties namely Black, BM-1, BM-3, BM-4, BM-5, BM-6, BM-7, BM-8, CPH-91, CPH-167, S-13 and S-30 were used in this study and incidence of three common diseases namely powdery mildew, leaf spot and tukra diseases were recorded.

Experimental design

The experiment was laid out in randomized complete block design (RCBD) with twelve varieties, three crop seasons and three diseases along with three replications (Plot size was 18ft × 12ft and plant to plant spacing was 3ft × 3ft).

Experimental procedure

For a period of two consecutive years, six numbers infected plants per disease were randomly selected in every replication and each cropping seasons. The plantation system was square high bush and plant height was 1 ft. In each cropping seasons data was collected 60 days after pruning. Disease incidence was assessed as number of total mulberry leaf per plant and number of total infected leaf per plant of a disease or any visible symptom of specific diseases in that plant.

Data collection

The necessary data was collected for each crop season from randomly selected disease infected plant. In case of late autumn season data was collected in October to November, in summer season March to April and in rainy season it was in June-July and July-August in each year. The incidence percentage of different diseases in mulberry leaf was calculated by following formula using by the Rai and Mamatha (2005).

$$\text{Percent Disease Incidence (PDI)} = \frac{\text{Number of diseased leaves on each plant}}{\text{Number of total leaves on each plant}} \times 100$$

Moreover monitoring of disease environment relation to epidemiological aspects of powdery mildew, leaf spot and tukra diseases have been carried out in this experiment. In these perspectives, the necessary meteorological data like air temperature, relative humidity (RH) and rainfall for the respective seasons were collected from local weather stations of Shampur, Rajshahi throughout the study period. The collected data were calculated for monthly mean of minimum and maximum temperature, mean of relative humidity and mean of rainfall of the respective locations and respective seasons.

Analysis of soil physical and chemical properties

Soil textural analysis was conducted by using an abbreviated version of the international pipette method. Clay content was determined by a pipette method after pretreatment with H_2O_2 to remove organic matter (Gee and Bauder, 1986). The pH of the soil was determined before incubation experiment in distilled water using a soil-to-solution ratio of 1:2.5. Organic carbon of the soil samples was determined by wet oxidation method (Walkley and Black, 1934). Soil organic matter content was determined by multiplying the percent value of organic carbon with the conventional Van-Bemmelen's factor of 1.724 (Piper, 1950). The nitrogen content of the soil sample was determined by distilling soil with alkaline potassium permanganate solution (Subhaiah and Asija, 1956). The distillate was collected in 20 ml of 2% boric acid solution with methylred and bromocresol green indicator and titrated with 0.02 N sulphuric acid (H_2SO_4) (Podder *et al.,* 2012). Soil available S (ppm) was determined by calcium phosphate extraction method with a spectrophotometer at 535 nm (Petersen, 1996). The soil available K was extracted with 1N NH_4OAC and determined by an atomic absorption spectrometer (Biswas *et al.,* 2012). The available P of the soil was determined by spectrophotometer at a wavelength of 890 nm. The soil sample was extracted by Olsen method with 0.5 M

Table 1: Physical and chemical properties of the experimental soil

Soil pH	Nitrogen (%)	Phosphorus (ppm)	Potassium (Cmol/Kg)	Sulphur (ppm)	Zinc (ppm)	Organic matter (%)
8.5	0.07	29.0	0.26	2.6	2.36	1.24

$NaHCO_3$ as outlined by Huq and Alam (2005). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Workman, 1979).

Statistical analysis

Some statistical analysis was conducted using Genstat 12.1th edn for Windows (Lawes Agricultural Trust, UK). Also, some analysis was conducted by Statistix 10 software. Treatment means were separated by the least significant difference (LSD) at a 0.05% level of significance (Steel and Torrie, 1984). Mulberry plant growth and composition data were analyzed by a one-way analysis of variance for the main effects of mulberry plant growth. Other parameters were statistically analyzed and mean values were evaluated by DMRT test.

RESULTS

Diseases infestation in different seasons

In this study 12 varieties of mulberry plants have been used in April 2013- June 2014 in BSRTI, Rajshahi. The highest mean disease incidence of powdery mildew was recorded as 1.76 % in variety S-30 and the lowest as 1.17 % in BM-7. DMRT results shows that rest of the varieties have no significant differences in disease occurrence (Table 2). In case of leaf spot disease of mulberry, variety BM-6 showed the highest disease incidence (1.73%) and variety Black recorded as 0.47%. Tukra disease of mulberry recorded the highest as 0.63% in BM-4 and the lowest as 0.15% in variety BM-10 and BM-11, but varieties S-13, BM-6 and BM-7 showed statistically similar results in this study (Table 2). It clears from our observation that among the three studied diseases, powdery mildew of mulberry showed the destructive disease than that of other two diseases (Table 2).

Similarly, 12 varieties of mulberry plants have been used in (October-December) for each year of 2012, 2013 and 2014. The maximum disease incidence of powdery mildew was recorded as 10.41% in variety BM-7 and minimum 2.47 % and 2.94 % in varieties BM-8 and BM-11 respectively. DMRT results shows that there are no significance differences in disease occurrences among rest of the varieties (Table 3). In case of leaf spot disease variety S-13 showed the highest incidence 8.49 % and variety BM-8 showed lowest incidence 2.47 % which is statistically similar with the variety of BM-11 (Table 3). On the other hand the occurrences of Tukra disease found to be maximum in variety Black (3.10 %) and minimum incidences recorded in variety BM-8 (0.53 %). DMRT results also presented that incase of Tukra disease rest of the varieties except BM-1 are statistically similar results in this study (Table 3). From our observation it is clear that among the three diseases, powdery mildew was destructive also in late autumn season than the other two diseases (Table 3).

Further, in rainy season (June-August) among the 12 mulberry varieties the highest mean powdery mildew disease incidences was recorded in variety S-13 (3.88 %) and the lowest incidence found to be in variety BM-11 (1.82 %). DMRT results shows that rest of the varieties have no significant differences in disease occurrence

Table 2: Incidence of mulberry diseases in different mulberry varieties during summer (April-June) crop season

Name of the varieties	Mean diseases incidence percentage (%)		
	Powdery mildew	Leaf spot	Tukra
Black	1.27^{ab}	0.47^{d}	0.31^{ab}
BM-1	1.60^{ab}	0.94^{bcd}	0.52^{ab}
BM-3	1.62^{ab}	1.30^{abc}	0.28^{ab}
BM-4	1.47^{ab}	1.70^{a}	0.63^{a}
BM-5	1.23^{ab}	1.35^{abc}	0.34^{ab}
BM-6	1.38^{ab}	1.73^{a}	0.16^{b}
BM-7	1.17^{b}	1.55^{ab}	0.19^{b}
BM-8	1.56^{ab}	0.90^{bcd}	0.21^{ab}
BM-10	1.37^{ab}	1.22^{abc}	0.15^{b}
BM-11	1.20^{ab}	0.67^{cd}	0.15^{b}
S-13	1.46^{ab}	1.54^{ab}	0.17^{b}
S-30	1.76^{a}	1.29^{ab}	0.30^{ab}

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

Table 3: Incidence of mulberry diseases in different mulberry varieties during late autumn (October–December) crop season

Name of the varieties	Mean **(%)** of different mulberry diseases infestation rate		
	Powdery mildew	Leaf spot	Tukra
Black	3.41^{d}	3.53^{ef}	3.10^{a}
BM-1	5.26^{c}	5.65^{bcd}	1.49^{b}
BM-3	9.19^{ab}	4.89^{cde}	0.67^{bc}
BM-4	8.73^{b}	1.08^{bcd}	0.68^{bc}
BM-5	9.09^{ab}	4.81^{cde}	1.21^{bc}
BM-6	5.33^{c}	4.17^{def}	0.80^{bc}
BM-7	10.41^{a}	6.33^{bc}	1.09^{bc}
BM-8	2.47^{d}	2.80^{f}	0.53^{c}
BM-10	4.89^{c}	5.07^{cde}	1.14^{bc}
BM-11	2.94^{d}	2.36^{f}	0.63^{bc}
S-13	8.09^{b}	8.49^{a}	1.13^{bc}
S-30	6.21^{c}	6.94^{ab}	0.75^{bc}

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

(Table 4). On the other hand the highest occurrences of leaf spot disease found to be 4.54 % in variety BM-1 which is statistically similar with the variety of BM-7 and the lowest incidence was recorded as 1.24 % in variety S-13 (Table 4). In case of Tukra disease the highest incidence found to be 1.21 % in BM-4 and lowest incidence was recorded in variety BM-10 (0.50%), but on the basis of DMRT results statistically there were no differences among the 12 varieties (Table 4). However, in our observation it is clear that in rainy season also among the three diseases powdery mildew was first, leaf spot second and Tukra disease was thirdly destructive for mulberry plant (Table 4).

Interaction of mulberry diseases and varieties in various crops seasons

The interaction among varieties and seasons were significant ($P \leq 0.01$) for leaf spot. However, it did not differ significantly ($P \geq 0.05$) for powdery mildew and Tukra disease. A significant ($P \leq 0.001$) difference was observed among the incidence percentage of powdery mildew, leaf spot and tukra diseases in three different crop seasons. But in the respect of mulberry varieties among the three diseases, only the tukra (mealy bug) disease was significantly ($P \leq 0.001$) susceptible for the infection percentage (Table 5).

Table 4: Incidence of mulberry diseases in different mulberry varieties during rainy (June-August) crop season

Name of the varieties	Mean (%) of different mulberry diseases infestation rate		
	Powdery mildew	Leaf spot	Tukra
Black	1.97^{cde}	2.36^{bcd}	1.04^{a}
BM-1	1.93^{de}	4.54^{a}	1.13^{a}
BM-3	1.97^{de}	3.29^{cd}	1.11^{a}
BM-4	3.01^{abc}	1.64^{de}	1.21^{a}
BM-5	3.05^{abc}	3.90 ^{ab}	1.14^{a}
BM-6	2.81^{bcdf}	3.32^{abc}	1.18^{a}
BM-7	2.86^{bcd}	3.98^{a}	0.77^{a}
BM-8	2.31^{bcdf}	3.29^{abc}	1.07^{a}
BM-10	3.31^{ab}	3.31^{abc}	0.5^{a}
BM-11	1.82^{e}	1.73^{de}	1.08^{a}
S-13	3.88^{a}	1.24^{e}	0.83^{a}
S-30	1.93^{de}	1.67^{de}	0.85^{a}

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

Table 5: Level of significance for the main and interactive effect of varieties and seasons among three diseases

Source of variation	Diseases incidence percentage		
	Powdery mildew	Leaf spot	Tukra
Seasons	***	***	***
Varieties	n.s.	n.s.	***
Varieties × Seasons	n.s.	**	n.s

Table 6: Average of two years different diseases infestation (%) among the mulberry varieties

Name of the varieties	Powdery mildew	Leaf spot	Tukra
Black	2.22	2.21	1.48
BM-1	2.93	3.71	3.14
BM-3	4.26	3.16	0.69
BM-4	4.40	1.47	0.84
BM-5	4.46	3.35	0.90
BM-6	3.17	3.07	0.71
BM-7	4.81	3.95	0.68
BM-8	2.11	2.33	0.60
BM-10	3.19	3.2	0.60
BM-11	1.99	1.59	0.62
S-13	4.48	3.76	0.71
S-30	3.3	3.3	0.63

Incidence of various diseases among varieties in respect of cropping seasons

The results indicated that all the twelve mulberry varieties were affected by the three diseases like- powdery mildew, leaf spot and tukra. The high incidence percentage of powdery mildew disease (1.76%) was observed in S-30 variety and significantly ($P \leq 0.05$) differed with that of the BM-7 mulberry variety in the summer season. However, other varieties did not show significantly ($P \geq 0.05$) differed. In case of leaf spot disease, the maximum incidence percentage was recorded (1.73%) in variety BM-6 which was significantly differed than that of Black (0.47%) and BM-11 (0.67%) but the other varieties were also not significantly differed. There were also the wide ranges of variation observed in respect of tukra disease. The highest occurrence of tukra disease was (0.63%) in variety BM-4 which was significantly differed with BM-10 (0.15%) and BM-11 (0.15%) respectively. Rest of the varieties was not significant. (Table 2).

Results showed that the maximum occurrence of powdery mildew disease was found 10.41% in variety BM-7 and was significantly higher than that of the other varieties in late autumn season. In case of leaf spot disease, the highest incidence percentage was 8.49 in S-13, which was significantly differed with the other mulberry varieties. The highest incidence percentage of tukra disease was found to be 3.10 in variety Black, which was significantly differed with the BM-1 (1.49%) but the other varieties were also not significantly differed (Table 3).

The highest incidence percentage of powdery mildew disease was observed as 3.88% in S-13 and was significantly higher than the other varieties in the rainy season. On the other hand in case of leaf spot disease the maximum occurrence percentage was found to be 4.54% in variety BM-1 mulberry which was comparatively higher than that of the rests varieties. The maximum incidence of tukra disease was found to be 1.21% in variety BM-4 but there was no significant difference among the varieties in the respect of incidence percentage (Table 4).

Incidence of different diseases among the mulberry varieties

Present results indicate that the maximum incidence percentage was recorded as 4.48 %, 4.46 % and 4.40 % in varieties S-13, BM-5 and BM-4 for the powdery mildew disease. However, the lowest powdery mildew disease incidence percentage was recorded as 1.99 %, 2.11 % and 2.22 % in varieties BM-11, BM-8 and Black (Table 6).

On the other hand comparatively the highest incidence percentage was recorded for leaf spot disease as 3.95 %, 3.76 % and 3.71% in varieties BM-7, S-13 and BM-1. However, lowest incidence percentage was observed 1.47 % and 1.56% in varieties of BM-4 and BM-11 (Table 6).

In case of tukra disease (Mealy bug) comparatively the maximum incidence was recorded 3.14% and 1.48% in varieties BM-1 and Black. But the lowest incidence percentage was found to be 0.60 %, 0.60%, 0.62% and 0.63% for mulberry varieties of BM-8, BM-10, BM-11 and S-30 respectively (Table 6).

Climatic conditions during study period

There was a great variation for the climatic conditions in the respect of cropping seasons were found in our studding. In summer season the maximum and minimum temperatures were 35.38°C and 24.76°C respectively, rainfall was 108.50 mm and relative humidity was 65.42% (Table 7).

In case of late autumn season the maximum and minimum temperatures were 27.52°C and 17.24°C respectively, rainfall was 66.00mm and relative humidity was 77.56 % (Table 7).

On the other hand in rainy season the maximum and minimum temperatures were 33.63°C and 26.60°C respectively, rainfall was 280.15 mm and relative humidity was 78.28% (Table 7).

Table 7: Average two year's temperature **(**min**.** and max**.)**, rainfall and relative humidity during the disease observation seasons

Weather parameters	Crop seasons		
	In summer	In late autumn	In rainy season
Temperature **(**˚C**)**	Maximum: 35.38˚C Minimum**:** 24.76˚C	Maximum: 27.52˚C Minimum: 17.24˚C	Maximum: 33.63˚C Minimum: 26.60˚C
Rainfall **(**mm**)**	108.50	66.00	280.15
Humidity **(%)**	65.42	77.56	78.28

DISCUSSION

Seasonal impact on occurrence of foliar mulberry diseases

The occurrences of foliar diseases are one of the limiting factors of production for healthy and nutritious mulberry leaves. We found that the foliar diseases like, powdery mildew (*Phyllactinia corylea*), leaf spot (*Pseudocercospora mori*) and tukra (*Maconellicocus hirsutus*, Green) occurred simultaneously more or less all the three crop seasons among the all mulberry varieties of Rajshahi region in Bangladesh. It was found that among the three diseases the occurrence of powdery mildew disease was comparatively highest in all the three crop seasons, which was 10.41% in late autumn season. The second highest incidence percentage was observed for leaf spot disease which was 8.49% in also late autumn season. Though the infection of tukra (Mealy bug) disease was too much limited but it was found more or less all the crop seasons. The highest incidence percentage was observed for tukra disease was 3.14% in late autumn season. In our study we found the occurrences of all three diseases more or less of all the three cropping seasons but among the three diseases and three cropping seasons the infection percentage was highest for powdery mildew disease in late autumn season. Previously in Bangladesh Pasha and Barman (1990) were conducted a general study on the incidence percentage of two diseases like- powdery mildew and leaf spot. They found that among the two diseases the highest occurrence was 54.33 % for powdery mildew and lowest incidence was 43.69 % for leaf spot disease, which is more or less similar with our findings.

However, in India Biswas *et al.* (2002) were studied on the occurrence of five mulberry diseases like powdery mildew, Anthracnose, Leaf rust, Red rust and Bacterial blight in three cropping seasons viz, Spring (April-May), Rainy (June-July) and Autumn (September-October) with four mulberry cultivars, namely, Kosen, BC_2 59, Tr-10 and S_{146}. They found that among the five mulberry diseases powdery mildew was occurred in all the three seasons, while, anthracnose mainly in rainy and leaf rust in autumn season. While in another study, Irfan *et al.* (2011) found among the leaf spot and powdery mildew diseases the occurrence of powdery mildew was prevalent throughout the valley and its incidence started during August with disease incidence (DI) and percent disease index (PDI) of 3.47 and 1.04, respectively and reached more severe in the month of October with DI and PDI of 5.71 and 2.15, respectively which is also more or less similar with our findings.

Though the incidence of tukra disease was found almost all the three crop seasons but it was lowest among the three diseases. The highest incidence percentage for tukra disease was found 3.10 % also in late autumn season. Similarly, Benchamin *et al.* (1997) recorded the infestation of mealy bug in mulberry crop throughout the year which was 0.79 to 11.69 percent but maximum severity was found in July to August. Our speculation is that the seasonal environment or climatic factors (temperature, humidity, rainfall), agronomical conditions and cultural practices are highly responsible for the specific disease infection. Similarly, Seema *et al.* (2010) reported that the impact of local agronomical conditions, mulberry variety, cultural practices and cropping seasons were responsible for the incidence and severity of different diseases. It would be due to the more susceptibility of climatic factors in late autumn season (October-December) for powdery mildew disease than the other two cropping seasons the highest infection percentage was observed for this disease.

Srikantaswamy *et al.* (2000) observed that the average of 24˚C temperature and relative humidity of not less than 60% are favorable for the development of leaf spot disease in mulberry plant which is more or less closely related with our climatic conditions of late autumn season, it would be due to climatic susceptibility the infection percentage of leaf spot disease was also second highest in late autumn season than the other two seasons. Likewise, in case of tukra disease our speculation was that due to the favorability of climatic conditions in late autumn season comparatively the other two cropping seasons the infection percentage of tukra disease was also higher. Similarly, Mahimasanthi *et al.* (2015), found the non significant positively correlation of higher ranged of temperature from 32˚C to 40˚C but they found average relative humidity ranged from 60 to 89% and rainfall ranged from 9.7 to 99.2 mm were comparatively susceptible for tukra disease infestation and population respectively.

Varietal response for mulberry disease incidence

Mulberry disease varies with respect to varieties. There was no so much significant variation for powdery mildew and leaf spot diseases infestation were observed with respect to various mulberry varieties. However, the tukra disease was significantly differed with respect to mulberry varieties and cropping seasons (Table 4). This study showed that high percentage of powdery mildew incidence was S-13 (4.48%), BM-5 (4.46%) and BM-4 (4.40%) out of 12 varieties (Table 5). Our findings showed that three varieties namely BM-11, BM-8 and Black have comparatively more resistant for powdery mildew among twelve varieties. Similarly, other varieties like S-13, BM-5 and BM-4 were high susceptible to the powdery mildew disease among twelve varieties. Previously, Rabbel (1995) worked on five mulberry varieties namely, Telia, BM-1, BM-3, BM-4 and BM-5. Among the five varieties he found that BM-3 and Telia varieties showed high powdery mildew severity which was 31.08% and 29.33% respectively. In contrast, BM-4

and BM-5 showed low severity which was 18.14% and 19.31% respectively. Similarly, Biswas *et al.* (1993), Gangwar and Thangavelu (1998) also identified some cultivars such as S-1, S-799 and *M. australis* which are resistant to powdery mildew disease.

Further, out of the twelve mulberry varieties the high infection percentage was found for leaf spot disease which was 3.95%, 3.76% and 3.71% in BM-7, S-13 and BM-1 varieties respectively. Our findings indicated that varieties BM-4 and BM-11 were comparatively more resistant to leaf spot disease. In contrast, varieties BM-7, S-13 and BM-1 were more susceptible to leaf spot disease (table 5). Earlier Rabbel (1995) worked on six mulberry varieties namely BM-1, BM-2, BM-3, BM-4, BM-5 and Telia. Among the six varieties he found that varieties BM-4 and BM-5 were comparatively resistant to leaf spot. On the other hand, varieties Telia, BM-1, BM-2 and BM-3 were comparatively susceptible to leaf spot disease. Other work conducted by Nderitu *et al.* (2012) found that the Embu accession was susceptible but Thika, S41 and Thailand accession were moderately susceptible, while Kanva-2 was resistant to leaf spot out of five mulberry accessions namely Embu, Thika, Thailand, Kanva-2 and S41.

In addition, among twelve varieties incidence of tukra (also known as mealy bug) disease was high in BM-1 and Black varieties like 3.14% and 1.48% respectively. In contrast, the low incidence was recorded 0.60%, 0.62% and 0.63% for BM-10, BM-11 and S-30 varieties respectively. This finding indicated that BM-1 and Black variety was comparatively more susceptible to tukra disease as compared to other varieties. In contrast, BM-10, BM-11 and S-30 varieties more resistant against tukra (also known as mealy bug) disease among other varieties. Similarly, in a previous study Sathyaprasad *et al.* (2000a) screened a mulberry variety Togowase (ACC No. 257) which was tolerant to the three sap suckers, namely, mealy bug (tukra disease), thrips and jassids. Besides, Sathyaprasad *et al.* (2000b) also screened certain ruling mulberry varieties, viz., S36, S34, S13, K2, and V1 for their tolerance to tukra disease through induction method.

In this study, the overall rating among the twelve varieties BM-11, BM-8 and Black were comparatively resistant to the P. mildew. Likewise, the varieties BM-4 and BM-11 were resistant to leaf spot disease. Similarly, BM-8, BM-10, BM-11 and S-30 were resistant to tukra (also known as mealy bug) disease. This could be due to the reason that the presence of some genetical (structural/anatomical) characteristics of these several varieties which defend themselves against pathogens by means of structural characteristics that act as physical barriers and block the passage of the pathogen into the host. Juniper and Cox (1973) also speculated that certain features like thick walled cells, more number of Palisade layers, significantly higher thickness of epidermis cum cuticle, comparatively thinner spongy parenchyma and significantly higher palisade proportion were present of these varieties which makes comparatively defence mechanism and give them protection from the infection of pathogen for the specific diseases. Likewise, Kulkarni and Deshpande (2006) stated that anatomical barriers, though passive, give required protection to the plant till the induction of chemical resistance which is more or less lines with our assumptions.

Conclusion

This study demonstrated that three common diseases occur in various cropping seasons of mulberry plant. The maximum infestation was observed for powdery mildew disease in late autumn season for BM-7 (10.41%) mulberry variety and lowest infestation was found for tukra (Mealy bug) disease in summer season for BM-10 (0.15%) and BM-11 (0.15%) respectively. The infestation was recorded 8.49% for S-13 variety in late autumn season but the highest infestation for tukra (Mealy bug) was found 3.10% in Black variety during late autumn season. This study also demonstrated that the infestation percentage and infestation period of different diseases like powdery mildew, leaf spot and tukra can be varied with the aspect of cropping season, climatic condition and varieties. Further study about control measure for these three common mulberry diseases practices will be conducted.

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