J. Mycopathol. Res. ***58(1&2)*** *: 39-45, 2020;* (ISSN 0971-3719)

Influence of different dates of sowing on diseases progression of Leaf Spot of Strawberry

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Received : 16.03.2020 Accepted : 08.04.2020 Published : 27.07.2020

Leaf spot of Strawberry caused by *Neopestalotiopsis clavispora*, is known to cause devastating damage to photosynthetic leaf area and fruit reducing its economic value wherever grown in the states of India. In North-eastern states as well as in West Bengal region too, strawberry is infected by this pathogen. Disease severity of eight varieties namely, Sabrina, Barak, Hadar, Sabrina1, Sweet Charlie, Gili, Winter Down and Crystal was recorded at two dates of planting 25/10/2016 and 06/12/2016. Irrespective of dates of planting Sabrina and Gili produced less disease and maximum yield and yield attributes. Effect of five weather parameters (Tmax, Tmin, RHmax, RHmin, soil temperature ST and Bright Sunshine Hours BSH) on disease severity showed that increase in Tmax (23.8 to 30.9^{0}c), Tmin (6.0 to 15.4^{0}c) and ST (12.6 to 20.3^{0}c) disease severity increased significantly and it was observed in all the varieties tested. Whereas, RHmax negatively and BSH positively were insignificantly correlated. Further, the prediction equation showed that in each varieties the disease severity depended upon the positive influence of Tmax and RHmin in combination with negative influence of Tmin, RHmin with a few exceptions. Whereas BSH showed negative influence on five varieties (Sabrina, Barak, Gili, Winter Down, Crystal) and positive in other three varieties (Hadar, Sabrina1 and Sweet Charlie). During this period of disease development weather variables were Tmax (23.8 to 30.9^{0}c), Tmin (6.0 to 15.4^{0}c), ST (12.6 to 20.3^{0}c), RHmax (95.1-99%) and BSH (4.9- 6.8 hrs).

Key words : Strawberry, Leaf spot, disease progression, AUPDC, weather parameters

INTRODUCTION

Strawberry (*Fragaria × ananassa* Duch.) is a widely grown hybrid species of the genus *Fragaria*. Native to temperate regions, but also grown in tropical and subtropical countries. In India, it is mainly grown in hilly regions of Nainital in Uttarakhand, Dehradun in Uttar Pradesh, Mahabaleshwar in Maharashtra, Kashmir Valley, Bangalore and Kalimpong in West Bengal, recently, strawberry is found to be grown successfully in plains of Maharashtra especially at Pune, Nashik and Sangali areas (Kumar *et al*., 2015). Also, it's gaining importance in North Eastern part of India as well as West Bengal. Though, strawberry represents a very profitable crop for the fresh market, the occurrence of diseases on flowers, fruit, leaves, crowns and roots play a significant role in reducing economic value. Among the various fungal diseases reported, Neopestalotiopsis leaf spot is one of the serious diseases that reduces its fruit quality and market value. Symptoms in leaf initially appear as small necrotic lesion with grey colour center and purplish brown margin scattered on leaves which later, coalesce together converting the green lamina into black nectrotic areas with black acervuli in the center. On fruit too small, circular, water soaked, sunken brown lesion can be seen that later convert into black necrotic spot with acervuli in the centre. Mahapatra *et al*. (2018) for the first-time reported leaf spot and fruit rot to be caused by *Neopestalotiopsis cravispora* from Indo Gangetic Plains of West Bengal. However, there was no articles regarding the influence of weather factors on progression of leaf spot disease in strawberry from this region. But date of sowing and meteorological parameters has a strong influence in disease severity (Mahapatra and Das, 2015; Devi et al.,2018). Therefore, present work was carried out with objective to study the influence of different date of sowing on disease progression of Leaf Spot of Strawberry. This can be help

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farmers decide the timing for planting in order to reduce the severity and achieve a good harvest.

MATERIAL AND METHODS

Planting Materials

Eight varieties of strawberry namely, Sabrina, Barak, Hadar, Sabrina1, Sweet Charlie, Gili, winter Down and crystal were procured from Kumar Flowrist Bioplant company, Pune, India and used for the study. These eight varieties were planted during winter season on two different dates of sowing. First planting was done at 25/10/2016 and another at 6/12/2016.

Experimental site

The experimental site was located in Gayesphur, KVK farm, Nadia, West Bengal where Strawberry was planted on raised seed bed (1m x 10 m) in open field condition. Three rows were planted within a single bed by maintaining plant to plant distance of 1.5 metre. Beds were covered with plastic mulch and fertigation at 19:19:19 (Suphala) was applied during bed preparation as well as foliar spray.

Disease severity assessment

Leaf showing typical necrotic lesion with grey colour centre and purplish brown margin was assessed for disease severity. Twenty leaves were randomly selected from each plant (three plant in each replicate). The infection on each leaf was rated using a numerical index (containing five infection category) ranging from 0, which represented no infection on the leaf, and 5, which represented infection that covered > 1/2 of the leaf area, or the leaf is destroyed. Disease severity was calculated using the equation developed by Towsend and Heuberger, (1943).

Disease severity (%) = [Ó(n × v)/4N] × 100, where, n = Number of leaves within infection category. v = Numerical value of each category, N = Total number of leaves.

Then the disease severity was averaged over the three replications and disease progress curves were plotted. For each replication the area under disease progress curve was calculated as per Wilcoxson *et al.* (1975). The formula was used as follows:

Where, Y_i = Severity at first observation

$$AUDPC = \sum_{i=1}^{n} \left[\frac{Y_{i+1} + Y_i}{2(X_{i+1} - X_i)} \right]$$

X_i = Time (days) at the first observation

N = Total number of observations

Disease severity was recorded at 36, 43, 50, 57, 64 Days after planting (DAP) for 1st date of sowing (25/10/2016) and at 36, 43, 50, 57, 64, 71, 78 and 85 DAP for 2nd date of planting (06/12/2016).

Harvesting of the crop

The fruits were harvested at maturity and fruit yield was recorded for all the varieties under study.

Monitoring environment in the field

The following environmental parameters was monitored –

1) Maximum and minimum temperature using a thermography.

2) Maximum and minimum relative humidity was determined. Using wet and dry thermometer computed with hygrographic measurement.

3) Soil temperature was recorded by soil thermometer.

4) Bright sunshine hour through sunshine recorder.

These data were collected from the All India Co-ordinated Research Project on Agricultural Meteorology, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal. Seven day mean of those weather parameter (variables) were recorded at morning (06.35 hours) and standard meteorological weeks for the entire period of disease assessment were worked out.

Mathematical modelling of course of epidemic

The prediction equation was worked out through multiple regression analysis (MRA) using SPSS computer software. Co-efficient of determination ($\mathbf{R^2}$) and Co-relation co-efficient (r) were also calculated and tested for significance at probability P> 0.05. For study of the multiple effects on dependent variables (increase in disease severity/

response variable Y) the multiple regression analysis was done (MRA) as a predictive equation:
$v = a + b_1x_1 + b_2x_2 \ldots b_nx_n$
Where,
v = predicted value
a = Intercept
b = partial regression coefficient for x_i (i = 1 to … n)
x_i = Independent variables (i = 1 to n) environmental parameters

RESULT AND DISCUSSION

Disease severity on first date of planting

In the first date of planting *i.e*, the 25th oct 2016 all the eight varieties produced initial symptoms at 36 days after planting. The severity of disease was different on different varieties and their differences were statistically significant (Table 1). Minimum disease severity (14.49%) was observed on Barak statistically at par with Sabrina, (15.03) and crystal (15.26%) and different with Sabrina1 (19%). Maximum disease obtained in Sweet Charlie (28.4%) followed by winter down (25.26%) statistically at par with Hadar (25.11%) and significantly differed with Gili (23.48%). Similar trend in disease severity was recorded at 43DAP, 50DAP, 57DAP and 64DAP with some variation in the disease severity within the varieties considered. It was observed that with increasing age of planting materials there was a decrease in disease severity per plant as the rate of development increase in disease severity per plant was very slow as per rate of development of new foliage in plants.

Disease severity on first date of planting

In 2nd date of planting too initial disease infection started at 36 days after planting and interesting to note that with increase in the age of plant the disease severity also increased significantly and it was observed in all the 8 varieties studied. In this planting date, the initial disease severity was also low in comparison to early date planting. At 36 DAP, minimum disease severity was observed in Sabrina (4.0%) followed by Barak (4.89%) Sabrina1 (6.0%), medium disease severity was recorded in the variety Sweet Charlie (8.15%) whereas, maximum disease severity was noticed in Winter down (11.25%) statistically at par with Hadar (11.59%) and significantly different with Crystal (10.33%). Similarly, at 43, 50, 57, 64, 71, 78 and 85 days after planting, disease severity increased with increase in age and the severity varied in different varieties and their differences were statistically significant (Table 2).

Disease severity on pooled of two dates of planting

The disease severity at two dates of planting was different and their difference was statistically significant irrespective of varieties grown. In every date of observation or every age of plant (when disease date was recorded), the two dates of planting showed significant difference in disease severity and 1st date of planting showed maximum disease severity in comparison to 2nd date of planting and their difference was statistically significant. The pooled analysis showed that disease severity was different in different age of plant and it was also noticed that some varieties showed increment of disease with increase in the age of plant and some varieties produced less disease with increasing age of the plant. The varieties which produced least disease with increase in age of the plants were Sabrina 1, Gili where as other six varieties produced incremental rate of disease with increase the age of plants (Table 3).

Yield attributes and Fruit Yield

The yield characters like numbers of fruits, Best weight, Average weight and total weight of fruits in different dates of planting were different in different varieties and their differences were statistically significant. The number of fruits was maximum in Sabrina (513 nos) followed by Sabrina 1 (393 nos), Gili (341 nos) and Sweet Charlie (326 nos) and minimum in Hadar (59 nos) followed by crystal (225nos) and winter down (275nos) and their differences were statistically significant. In case of best weight maximum was observed in Sabrina (44.0 g) statistically at par with Winter down (41.0g), Sweet Charlie (39.0g) and minimum in Barak (26.67g) statistically at par with Crystal (32.0 g). Average weight (g) was maximum in Sabrina (36.63g) followed by sweet Charlie (34.0g) and minimum in Barak (22.4g) followed by winter down (26.70g) which was statistically at par with Sabrina 1 (27.36g) and Crystal (29.10g). Also, total weight of fruits (kg/ ha) showed maximum in Sabrina (14,507.33 kg/ha) followed by Gili (11,070 kg/ha), Sabrina 1 (10,553.00 kg/ha) and Barak (10,292.00

Table 1: Disease progression of leaf spot of strawberry on different varieties on the 25th October, 2016 Planting

Variety	Disease severity (%)				
	36 DAP	43 DAP	50 DAP	57 DAP	64 DAP
Sabrina	15.03	13.04	10.13	9.23	8.67
Barak	14.49	13.11	12.15	11.44	9.64
Hadar	25.11	21.22	17.48	16.16	15.33
Sabrina1	19.00	18.06	16.56	15.54	12.26
Sweet Charlie	28.40	26.59	25.26	22.19	20.37
Gili	23.48	22.19	18.48	15.31	13.44
Winter Down	25.26	24.47	23.37	20.2	18.34
Crystal	15.26	16.15	15.54	14.22	10.42
SEm ±	0.41	0.32	0.14	0.15	0.19
CD(0.05)	1.26	0.96	0.43	0.45	0.59

kg/ha) and their differences were statistically significant. Finally, it was observed that the less disease produced by Sabrina also produced maximum yield with less disease severity and good harvest of the fruits (Table 4).

Disease progress as a function of standard weather parameters on different varieties at two dates of planting

The result showed that in every date of planting all the five weather factors Tmax, Tmin (°C) RHmax, RHmin (%) and BSH were positively or negatively and significantly influenced on disease

Table 2: Disease progression of leaf spot of strawberry on different varieties on the 6th December, 2016 Planting

Variety	Disease severity (%)							
	36 DAP	43 DAP	50DAP	57DAP	64DAP	71 DAP	78 DAP	85DAP
Sabrina	4.00	5.34	7.01	8.99	9.58	10.98	14.19	15.26
Barak	4.89	7.11	7.74	9.95	11.59	12.78	16.41	19.61
Hadar	11.59	11.21	12.67	15.63	18.00	21.00	22.67	25.59
Sabrina1	6.00	7.08	8.59	9.97	11.72	16.77	17.37	18.26
Sweet Charlie	8.15	8.71	9.33	10.54	13.64	16.56	17.49	21.37
Gili	8.50	9.34	9.71	10.08	12.41	13.01	14.00	18.48
Winter Down	11.25	13.19	15.16	20.28	22.29	24.15	25.67	27.54
Crystal	10.33	11.46	12.65	14.96	19.56	23.05	25.44	26.37
SEm ±	0.15	0.23	0.28	0.26	0.22	0.35	0.35	0.34
CD(0.05)	0.47	0.71	0.85	0.78	0.67	1.07	1.06	1.04

Table 3: Disease progression of leaf spot of strawberry on different varieties on pooled of two dates of Planting

Variety	Disease severity (%)				
	36 DAP	43 DAP	50DAP	57DAP	64DAP
Sabrina	9.52	9.19	8.57	9.112	9.13
Barak	9.69	10.11	9.94	10.697	10.61
Hadar	18.35	16.21	15.07	15.905	16.67
Sabrina1	12.5	12.57	12.58	12.753	11.99
Sweet Charlei	18.27	17.65	17.29	16.365	17.00
Gili	15.99	15.76	14.09	12.698	12.92
Winter Down	18.25	18.83	19.27	20.24	20.32
Crystal	12.79	13.80	14.09	14.59	14.99
SEm ?	0.22	0.19	0.16	0.15	0.15
CD(0.05)	0.64	0.57	0.45	0.43	0.43
1st sowing	20.75	19.35	17.371	15.539	13.56
2nd sowing	8.09	9.18	10.358	12.551	14.85
SEm ?	0.08	0.13	0.053	0.107	0.09
CD(0.05)	0.32	0.51	0.208	0.420	0.37

Table 4: Yield and yield characters of varieties of Strawberry

Varieties	No. of fruits	Best weight (g)	Avg. wt. (g)	Total weight (kg/ha)
Sabrina	513	44.0	36.63	14,507.33
Barak	409	26.67	22.43	10,292.00
Hadar	59.0	35.67	29.69	3,691.00
Sabrina	393.0	37.67	27.36	10,553.33
Sweet Charlie	326.0	39.00	34.00	9,795.00
Gili	341.0	38.33	29.45	11,070.00
Winter down	275.0	41.00	26.70	8,855.00
Crystal	225.0	32.0	29.10	9100.00
SEm±	0.44	1.85	0.84	25.76
CD at 5%	1.34	5.68	2.56	109.53

severities in all the eight tested varieties. In both the dates of planting (1st and 2nd) multiple regression analysis of each variety showed different prediction equations due to different disease severity against the same weather variables. Prediction equation of each date is given in table 5 and 6 respectively. However, to better understand the relationship between disease severity in each variety and weather parameter correlation coefficient was worked out.

Table 5: Prediction equations of disease severity of eight different varieties on 1st date of planting

Variety	MRA equation	R^2 Value
Sabrina	Y= 106.92 – 0.74 Tmax – 2.58 Tmin+1.00 RHmax+0.76 RHmin+0.83 BSH	0.98
Barak	Y = 102.61 – 2.66 Tmax + 1.82 Tmin – 0.44 RHmax – 0.12 RHmin + 0.85 BSH	0.99
Hadar	Y = – 390.63 + 8.46 Tmax - 5.21 Tmin + 3.12 RHmax – 0.29 RHmin – 5.27 BSH	0.89
Sabrina 1	Y = 167.41 – 4.23 Tmax + 2.56 Tmin – 0.79 RHmax – 0.08 RHmin + 1.33 BSH	0.98
Sweet Charlie	Y = 168.75 – 2.98 Tmax + 2.08 Tmin – 0.96 RHmax – 0.15 Rhmin + 1.29 BSH	0.99
Gili	Y = 112.19 – 3.34 Tmax + 2.31 Tmin – 0.47 RHmax – 0.11 RHmin + 1.55 BSH	0.88
Winter Down	Y = 162.56 – 2.56 Tmax + 1.52 Tmin – 1.01 RHmax – 0.06 RHmin + 1.17 BSH	0.90
Crystal	Y = 162.11 – 3.34 Tmax + 1.55 Tmin – 0.92 RHmax – 0.04 RHmin + 0.93 BSH	0.97

Table 6: Prediction equations of disease severity of eight different varieties on 2nd date of planting

Variety	MRA equation.	R^2 Value
Sabrina	Y= 56.89 + 1.26 Tmax – 1.28 Tmin – 0.73 RHmin + 0.16 RHmax – 1.26 BSH	0.99
Barak	Y = 94.77 + 0.131 Tmax – 5.39 Tmin – 0.78 RHmin + 1.21 RHmax – 3.76 BSH	0.70
Hadar	Y = 23.25 + 1.21 Tmax - 1.77 Tmin – 0.45 RHmin + 0.36 RHmax – 0.18 BSH	0.73
Sabrina 1	Y = 51.97 + 0.51 Tmax – 1.72 Tmin – 0.80 RHmin + 0.39 RHmax – 3.60 BSH	0.75
Sweet Charlie	Y = 65.47 + 0.36 Tmax – 1.18 Tmin – 0.77 RHmin + 0.38 RHmax + 0.18 BSH	0.70
Gili	Y = 66.42 + 0.014 Tmax – 3.04 Tmin – 0.55 RHmin + 0.79 RHmax – 2.29 BSH	0.63
Winter Down	Y = 4 1.51 + 0.93 Tmax – 6.46 Tmin – 0.40 RHmin + 1.21 RHmax – 1.98 BSH	0.78
Crystal	Y = 101.14 + 0.17 Tmax – 4.66 Tmin – 1.03 RHmin + 1.20 RHmax – 1.50 BSH	0.73

Table 7: Correlation co-efficient values of weather parameters against disease severity on different varieties on 1st date of planting

Variety	Tmax 24.7°C to 25.8 °C	Tmin 9.15 °C to 13.52°C	RHmax 93.71% to 99.0 %	ST 12.86 to 18.12 °C	BSH 2.18 to 7.51 hours
Sabrina	-0.71	0.46	-0.14	0.71	0.74
Barak	-0.62	0.39	-0.25	0.81	0.60
Hadar	-0.76	0.51	-0.06	0.74	0.71
Sabrina 1	-0.47	0.26	-0.40	0.77	0.57
Sweet Charlie	-0.60	0.24	-0.33	0.67	0.74
Gili	-0.57	0.24	-0.36	0.64	0.78
Winter Dawn	-0.50	0.12	-0.44	0.61	0.75
Crystal	-0.12	-0.07	-0.67	0.57	0.43

r>0.88 and r>0.96 are significant at 5% and 1% level respectively

Table 8 : Correlation co-efficient values of weather parameters against disease severity on different varieties on 2nd date of planting

Variety	Tmax 23.78 °C to 30.88 °C	Tmin 6.0 to 15.4 °C	RHmax 92.57% to 99.0%	ST 12.61 to 20.28 °C	BSH 4.93 to 8.62 hours
Sabrina	0.91	0.71	-0.60	0.90	0.37
Barak	0.93	0.77	-0.52	0.95	0.33
Hadar	0.95	0.79	-0.44	0.92	0.31
Sabrina 1	0.89	0.70	-0.50	0.89	0.35
Sweet Charlie	0.94	0.82	-0.39	0.95	0.29
Gili	0.92	0.83	-0.33	0.96	0.30
Winter Dawn	0.88	0.65	-0.52	0.85	0.38
Crystal	0.91	0.75	-0.49	0.92	0.25

r>0.71 and r>0.83 are significant at 5% and 1% level respectively

Disease progress as a function of standard weather parameters on different varieties at first dates of planting

During 1st date of sowing it was observed that all the considered meteorological factors were positively correlated with disease severity except Tmax and RHmax which were negatively correlated for all the varieties. It was also observed that maximum correlation co-efficient value was observed against soil temperature (St) followed by bright sunshine hours (BSH) and maximum temperature (Tmax) for all the tested varieties. Whereas, minimum correlation co-efficient values were obtained in maximum Relative humidity and minimum temperature for the varieties tested. Though in this planting season the above meteorological factors were not significantly correlated with increase in the disease severity (Table 7).

Disease progress as a function of standard weather parameters on different varieties at second dates of planting

In case of 2nd date of planting correlation between Area under disease progress curves (AUDPC) v.s five weather parameters showed that Tmax, Tmin and soil temperature were positively and significantly correlated with disease severity whereas, maximum relative humidity (RH max) negatively and bright sunshine hours (BSH) positively correlated with disease though their relations were not statistically significant. It indicated that with increase in maximum temperature (from 23.78 °C to 30.88°C), minimum temperature (6.0 to 15.4 °C), soil temperature (12.61 to 20.28°C) the disease severity increased significantly for all the varieties except Sabrina 1 & Winter dawn were Tmin showed no significant correlation. The other factors like maximum relative humidity showed negative correlation indicating that with increase in RH max (92.57% to 99.0%) there was a decrease in disease severity whereas, bright sunshine hours showed a positive correlation in disease severity indicating that with increase in BSH (4.93 hours to 8.62 hours) there was an increase in diseases severity though the relation was not significantly correlated and it was observed in all the eight tested varieties (Table 8).

CONCLUSION

In the present study it was found that irrespective of date of planting initial disease was observed at 36 days after planting. Late planting cause minimum disease irrespective of varieties as the disease usually developed when the plants are 8-week-old owing to poor inoculum load at later period. Among eight varieties, Sabrina produced minimum disease irrespective of dates of planting. Mouden *et al*. (2014) also found artificial inoculation of spore suspension of *P. longisetula* in tested varieties under study, Sabrina variety showed better disease resistance compared to another variety 'Festival'. Interestingly, Sabrina which produced less disease in this study was also found to produce maximum yield and yield attributes. Further correlation of disease severity with weather factors suggest increase in Tmax (23.8 to 30.9^{0}c), Tmin (6.0 to 15.4^{0}c), ST (12.6 to 20.3^{0}c), disease severity increased significantly and it was observed in all the varieties. Whereas, RHmax negatively and BSH positively insignificantly correlated. Further multiple regression analysis gave prediction equation indicating that in each

varieties the disease severity depended upon the positive influence of Tmax and RHmin in combination with negative influence of Tmin, RHmin with a few exceptions. The result was in conformity with the experimental proof of Embaby (2007) that the disease cause severe fruit damage in high relative humidity in cool season. The disease caused by *Pestalosia* sp. on other crops and their effect on weather parameters were reported by Mustafa *et al*. (2015) on guava that temperature & relative humidity has a high correlation for disease initiation and disease development. Further, Suterman *et al.* (2011) found that, rain fall, relative humidity and temperature are the weather components significantly affect the increase of the needle blight disease severity on *Pinus merkusii* seedlings incited by *Pestalotia theae*. They too found that a nursery with 26.5-30.5°C and RH: 92-98 %, is the most optimal requirement for the development of the disease. The findings cited above were in conformity with our findings.

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