RESEARCH ARTICLE

EVALUATION OF FIFTY WHEAT (*TRITICUM AESTIVUM* L.) GENOTYPES USING CHLOROPHYLL INDEX CANOPY TEMPERATURE DEPRESSION AND SPOT BLOTCHUNDER TERAI AGROCLIMATIC CONDITIONS OF WEST BENGAL

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Abstract: During the *rabi* season of 2020-2021, the experiment was conducted at the university instructional farm, Uttar Banga Krishi Vishwavidyalaya, Pundibari, Cooch Behar, West Bengal, to evaluate 50 wheat genotypes for chlorophyll index, canopy temperature depression, and spot blotch in the terai regions of West Bengal, as part of the 19th High-Temperature Wheat Yield Trail nursery from CIMMYT. Two-way ANOVA analysis revealed significant divergence in growth stages in all three cases. Six genotypes showed high chlorophyll efficiency at maturity whereas thirteen genotypes showed higher physiological efficiency in the present environment. Among them, only ENTRY 8 and 28 showed both and are recommended for future drought tolerance breeding. No genotype was found to be resistant to spot blotch, thus none is recommended for disease resistance breeding. According to a correlation study, when the area under chlorophyll index progress curve value rises, biomass rises, canopy temperature declines, and physiological efficiency rises. Furthermore, high chlorophyll index levels are linked to increased disease severity.

Keywords: Chlorophyll index, Canopy temperature depression, Spot blotch, Disease severity, Wheat

INTRODUCTION

Wheat was the second most important staple crop in India, behind rice, with a higher genetic variety in nearly all countries (Thakur *et al*., 2018, Soumitra *et al*., 2016).CIMMYT divides the globe's numerous wheat-producing zones into multiple mega-settings, and advanced breeding lines are dispersed to a range of circumstances across the world, with a focus on genotype evaluation for increased flexibility and selection for specific situations (Rajaram *et al*., 1995, Braun *et al*., 2010).Every year, the High-Temperature Wheat Yield Trial (HTWYT) nursery delivers improved breeding lines for heat-stressed locations to internal collaborators.

Previous research has shown that the role of morpho-physiological factors in wheat adaptation is dependent on the severity of drought stress (Chahbar and Belkhodja, 2016). Because canopy temperature depression (CTD) and chlorophyll content are associated with a variety of adaptive physiological parameters, they aid breeders in determining wheat yield stability (Saxena *et al*., 2014, Shefazadeh *et al*., 2012). Stomatal conductance (Reynolds *et al*., 2005), transpiration rate (Gautam *et al*., 2015, Davies *et al*., 2005), water use (Reynolds *et al*., 2005), leaf area index (Othmani *et al*., 2015), root characteristics (Man *et al*., 2016), and grain yield (Olivares-Villegas *et al*., 2007) are all positively associated with CTD. Photoinhibition, high membrane thermo-stability, and water use are all favorably associated with chlorophyll content (Fotovat *et al*., 2007). Furthermore, chlorophyll content is regarded as a valid indication of water use efficiency (WUE) and drought stress response in wheat (Fotovat *et al*., 2007).As a result, developing wheat cultivars that can more efficiently use available water and withstand drought is a primary priority for enhancing wheat production in water-stressed regions, and nations should implement policies that allocate water to adapt to climate change (Daxit *et al*., 2018, Condon *et al*., 2002, Kirigwi *et al*., 2004, Saadi *et al*., 2015).

West Bengal isn't known for its wheat production, because rice–wheat is the most common crop, it is subjected to a variety of biotic and abiotic stressors. As a result of the late harvest of paddy, terminal heat stress is a serious worry (Dubey *et al*., 2020). After February, the temperature begins to climb, which has a negative impact on the crop. Disease incidence is also elevated due to the presence of excessive humidity (Gupta *et al*., 2018). *Bipolaris sorokiniana* (Sacc.) Shoem's spot blotch or foliar blight disease is one of the most deadly diseases discovered in this area (Chowdhury *et al*., 2013). In susceptible genotypes, this is a dangerous disease that causes little dark brown lesions on the leaf that quickly congeal and spread.The eastern Gangetic plains of South Asia, which include India, Nepal, and Bangladesh, are the most severely affected (Sharma and Duveiller, 2006, Sharma *et al*., 2007). In India, average yield losses due to spot blotch have been estimated to be 15.5 percent (Dubin and Van Ginkel, 1991) and 17% (Saari, 1998), with grain yield losses ranging from 17.63 percent to 20% under favorable conditions (Goel *et al*., 2006). However, in the event of a severe infestation, yield loss might exceed 80%.

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(Joshi *et al*., 2007). The Terai region of West Bengal is known for its high humidity and short winter season, making it a hotspot for spot blotch (Kumar *et al*., 2016).

The objective of the present study was to see the effect of chlorophyll content, canopy temperature depression, and spot blotch on 50 wheat genotypes in different growth stages in the terai agroclimatic conditions of West Bengal.

MATERIALS AND METHODS

The experimental material (19 HTWYT nursery) has 50 genotypes, one of which is a check (Table 1). During the *rabi* season of 2020-2021, the research was conducted at the university instructional farm, Uttar Banga Krishi Vishwavidyalaya, Pundibari, Cooch Behar, West Bengal. The farm is 43 m above sea level and is located at 26°19'86" N latitude, and 89°23'53" E longitude. The genotypes were planted and harvested on time using a Randomised Complete Block Design with a plot size of 2.5 m × 1 m (6 rows plot^{-1}), and a row to row spacing of 20 cm. To grow a productive harvest, the appropriate cultural practices were followed.

Study of physiological traits

Chlorophyllindex

A Field Scout CM 1000 chlorophyll metre was used to measure the Chlorophyll index at four different crop growth stages: 88 DAS, 95 DAS, 102 DAS, and 109 DAS. Using the laser guide lights, the metre was directed at target row segments, and the value obtained was displayed quickly. Between the hours of 10 a.m. and 2 p.m., readings were taken with the sun behind the reader and the ambient light receiver unobscured. The CM 1000 metre measurements were taken 3 to 5 feet from the wheat canopy surface at 45° or 90° angles. The chlorophyll index value is only calculated if the ambient light intensity is more than one on a scale of 1-9. The measurements are collected in a circular area of roughly 13-35 square inches (at 3-5 feet from the canopy), which is densely covered in plants and leaves. The following formula was derived from Rosyara *et al*., (2007) to determine the Area Under Chlorophyll Index Progress Curve (AUCIPC).

$$\text{AUCIPC} = \sum_{i=1}^{n-1} 1/2\ (\text{Si} + 1 + \text{Si})\ \text{d} \quad \ldots(1)$$

Where, S_i = Chlorophyll index value at the end of time 'i', S_{i+1} = Chlorophyll index value at the end of time 'i+1', d = Day's interval between two observations, n = number of times of recording the value. Mean AUCIPC was calculated further.

Canopy temperature depression

An AR20 (Intell smart) infrared thermometer was used to measure the canopy temperature twice, at 68 DAS and 93 DAS. The same infrared thermometer was used to get the air temperature by focusing it on a blank sheet (white paper) positioned slightly above each plot before recording the canopy temperature. By subtracting the canopy temperature from the air temperature, the Canopy Temperature Depression (CTD) was computed (Balota *et al*., 2008).

Study of spot blotch disease

In this study, spot blotch (*Bipolaris sorokiniana*) (Sacc) Shoem was scored using the Double-Digit scale (Saari and Prescott, 1975, Eyal *et al*., 1987) at four crop growth stages: 88 DAS, 95 DAS, 102 DAS, and 109 DAS. The first digit (D_1) represents disease progression from ground level to canopy height, while the second (D_2) represents disease severity as measured by diseased leaf area. On a scale of 1-9, D_1 and D_2 are both rated. The proportion of disease severity is calculated for each score using the formula:

$$\text{Severity (\%)} = (D_1/9) \times (D_2/9) \times 100 \quad \ldots(2)$$

Area Under Disease Progress Curve (AUDPC) was calculated by using the formula given by Wilcoxson *et al*., (1975)

$$\text{AUDPC} = \sum_{i=1}^{n-1} 1/2\ (\text{Xi} + 1 + \text{Xi})\ \text{d} \quad \ldots(3)$$

Where, X_{i+1} = Disease severity on 'i+1'th day, X_i = Disease severity on 'i'th day, d = Day's interval between two observations, n= number of dates on which the disease was recorded. Mean AUDPC was further determined. Genotypes were classified as per AUDPC values suggested by Liatukas and Ruzgas, 2012. The AUDPC scale is as follows:

AUDPC value	Type of resistance
< 100.0	Resistant (R)
100.1-150.00	Moderately Resistant (MR)
150.1-200.00	MR-MS
200.1-250.00	Moderately susceptible (MS)
250.1-300.00	MS-S
300.1-350.00	S
350.1-400.00	S-HS
> 400.00	Highly susceptible (HS)

Table 1. List of wheat genotypes evaluated in 2020-2021

S. N	Genotype	Pedigree
1	ENTRY 1	DBW 187 (LOCAL CHECK)NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/KACHU
2	ENTRY 2	NADI#1
3	ENTRY 3	WBLL1*2/BRAMBLING/4/BABAX/LR42//BABAX*2/3/SHAMA*2/5/…
4	ENTRY 4	QUAIU#1/SUP152
5	ENTRY 5	PBW343*2/KUKUNA/3/PASTOR//CHIL/PRL/4/GRACK/5/MUU/…
6	ENTRY 6	CHIBIA//PRLII/CM65531/3/FISCAL*2/4/TAM200/TURACO/5/…
7	ENTRY 7	WBLL1*2/BRAMBLING*2//BAVIS/3/CHYAK1/VILLA JUAREZ F2009/…
8	ENTRY 8	KACHU//WBLL1*2/BRAMBLING*2/6/BECARD#1/5/KIRITATI/4/…
9	ENTRY 9	SUP152/BAL#1*2/3/KINGBIRD#1//INQALAB 91*2/TUKURU
10	ENTRY 10	SUP152/BAL#1*2/3/KINGBIRD#1//INQALAB 91*2/TUKURU
11	ENTRY 11	SUP152/BAL#1*2/3/KINGBIRD#1//INQALAB 91*2/TUKURU
12	ENTRY 12	SUP152/BAL#1*2/3/KINGBIRD#1//INQALAB 91*2/TUKURU
13	ENTRY 13	SUP152/BAL#1*2/3/KINGBIRD#1//INQALAB 91*2/TUKURU
14	ENTRY 14	TUKUU//BAV92/RAYON/3/FRNCLN/4/2*FRNCLN*2/TECUE#1
15	ENTRY 15	ABLEU*2/BORL14
16	ENTRY 16	MILAN/KAUZ//BABAX/3/BAV92/4/WHEAR//2*PRL/2*PASTOR/5/…
17	ENTRY 17	KENYA SUNBIRD/2*KACHU//KFA/2*KACHU
18	ENTRY 18	BAVIS/NAVJ07//SUP152/BAJ#1
19	ENTRY 19	CHIPAK*2//SUP152/KENYA SUNBIRD
20	ENTRY 20	WBLL1*2/CHAPIO/6/CNDO/R143//ENTE/MEX175/3/AE.SQ/4/…
21	ENTRY 21	HEILO//MILAN/MUNIA/3/KIRITAII/2*TRCH/4/2*KACHU/KIRITATI
22	ENTRY 22	CHIBIA//PRLII/CM65531/3/FISCAL*2/2/TAM200/TURACO/5/…
23	ENTRY 23	WBLL1*2/BRAMBLING*2//BAVIS*2/4/SWSR22T.B.//…
24	ENTRY 24	BECARD/FRNCLN//BORL14
25	ENTRY 25	TACUPETO F2001*2/KIRITATI//BLOUK#1/3/WBLL1*2/…
26	ENTRY 26	QUAIU#1/BECARD/3/WBLL1*2/BRAMBLING*2//BAVIS
27	ENTRY 27	BORL14*2/8/REH/HARE//2*BCN/3/CROC 1/AE.SQUARROSA (213)/…
28	ENTRY 28	BORL14*2/8/REH/HARE//2*BCN/3/CROC 1/AE.SQUARROSA (213)/…
29	ENTRY 29	SWSR22T.B./2*BLOUK#1//WBLL*2/KURUKU/3/BORL14/4/…
30	ENTRY 30	ELVIRA/5/CNDO/R143//ENTE/MEX175/3/AE.SQ/4/2*OCI/6/VEE/…
31	ENTRY 31	BOKOTA/3/ND643/2*WBLL1//2*BAJ#1
32	ENTRY 32	SUP152/BAJ#1/3/SWSR22T.B./2*BLOUK#1//WBLL1*2/KURUKU
33	ENTRY 33	MUTUS//ND643/2*WBLL1/3/BORL14
34	ENTRY 34	SHA7//PRL/VEE#6/3/FASAN/4/HAAS8446/2*FASAN/5/CBRD/KAUZ/…
35	ENTRY 35	KACHU/SAUAL//PRL/3/KACHU/KIRITATI
36	ENTRY 36	ROLF07//LALBMONO1*4/PVN/3/BORL14
37	ENTRY 37	NADI*2/3/EBW10 TALL#1/WESTONIA-Rht5//NAVJ07
38	ENTRY 38	SUP152/BAJ#1*2/4/WHEAR/VIVITSI//WHEAR/3/PANDORA
39	ENTRY 39	BECARD/FRNCLN//2*BORL14
40	ENTRY 40	BECARD/FRNCLN//KACHU/KIRITATI/3/BOKOTA
41	ENTRY 41	ATTILA/3*BCN//BAV92/3/PASTOR/4/TACUPETO F2001*2/…
42	ENTRY 42	MUNAL*2/WESTONIA/3/WBLL1*2/BRAMBLING*2//BAVIS/4/…
43	ENTRY 43	ROLF07*2/SHORTENED SR26 TRANSLOCATION//MUNAL#1/3/…
44	ENTRY 44	MUTUS*2//TAM200/TURACO*2/3/KFA/2*KACHU
45	ENTRY 45	MUTUS*2//TAM200/TURACO*2/3/KFA/2*KACHU
46	ENTRY 46	MUTUS*2/HARIL#1*2/3/SWSR22T.B./2*BLOUK#1//WBLL1*2/…
47	ENTRY 47	PASTOR//HXL7573/2*BAU/3/WBLL1/4/SOKOLL/3/PASTOR//…
48	ENTRY 48	ISENGRAIN/KBIRD//MUNAL#1*2/3/KFA/2*KACHU
49	ENTRY 49	CROC 1/AE.SQUARROSA (205) //BORL95/3/PRL/SARA//TSI/…
50	ENTRY 50	CROC 1/AE.SQUARROSA (205) //BORL95/3/PRL/SARA//TSI/…

RESULTS AND DISCUSSION

Study on physiological characters

Chlorophyll index

At four different crop growth stages, the Chlorophyll index tests revealed substantial differences across genotypes and growth phases. The genotype x growth stage interaction, on the other hand, was determined to be non-significant (Table 2). With the progression of development phases, the mean value of CI revealed a progressive drop in chlorophyll index (Table 3). This might be related to the progressive loss of chlorophyll pigmentation as the crop matures. However, among the 50 genotypes studied, the rate of decline in CI value was shown to be significantly varied.

Table 2. Two-way Analysis of variance of chlorophyll Index under different growth stages

Source of variation	df	Mean sum of square
Genotype	49	1629.00*
Growth stage	3	112427.00***
Genotype x Growth stage	147	962.00
Error	199	1016.00

*$p<0.05$ and ***$p<0.001$

Table 3. Two-way mean table for chlorophyll Index under different growth stages

GENOTYPE	88 DAS	95 DAS	102 DAS	109 DAS
1	181.900	218.800	192.300	155.400
2	171.100	182.500	158.600	104.900
3	166.800	199.100	150.500	86.200
4	178.600	195.000	135.100	99.700
5	134.300	144.900	132.300	94.400
6	181.200	169.300	131.200	82.300
7	161.900	162.700	142.200	102.800
8	207.800	182.900	169.000	113.800
9	193.900	171.300	158.900	114.000
10	234.800	169.100	127.600	91.200
11	199.500	178.500	160.200	104.400
12	178.700	171.700	159.700	94.900
13	176.000	158.700	126.400	86.100
14	192.800	170.200	154.200	126.800
15	187.700	150.200	151.800	99.400
16	166.100	197.900	153.500	92.500
17	216.900	152.700	165.000	104.200
18	164.300	145.500	146.500	105.200
19	206.700	199.400	156.900	92.800
20	182.700	163.100	148.700	93.100
21	214.400	156.500	162.000	116.100
22	146.900	146.400	137.600	102.100
23	159.100	174.600	147.500	98.400
24	171.400	176.900	121.600	85.100
25	165.200	135.700	137.900	108.500
26	171.500	168.500	170.500	108.000
27	165.400	209.800	153.400	177.800
28	202.400	169.600	202.700	133.300
29	188.600	205.700	168.000	120.400
30	168.800	149.300	143.300	108.000
31	151.900	148.200	130.100	88.600
32	205.200	168.200	148.400	98.300
33	159.400	145.500	161.300	95.000
34	183.400	163.400	147.200	104.000

35	188.500	183.000	144.300	87.700
36	199.200	146.800	194.600	122.100
37	151.500	125.500	132.000	95.800
38	161.700	178.900	130.400	88.800
39	169.100	165.800	178.700	121.800
40	176.300	163.100	143.600	86.700
41	154.600	152.000	139.100	117.500
42	162.900	149.800	128.100	108.900
43	220.400	170.500	148.800	81.300
44	165.000	149.000	165.200	97.700
45	174.500	146.900	136.800	96.400
46	160.900	150.300	163.400	95.900
47	145.300	155.300	126.900	92.800
48	159.300	146.200	121.000	79.600
49	162.600	150.800	122.200	94.800
50	170.000	178.200	127.000	87.600
Mean	177.182	166.278	149.084	102.862

ENTRY 10 (234.800) represents the greatest CI value in the first growth stage, whereas ENTRY 5 (134.300) represents the minimum value. ENTRY 1 (218.800) shows the highest value in the second growth stage, while ENTRY 37 (125.5) shows the lowest. ENTRY 28 (202.700) has the highest value in the third development stage, while ENTRY 48 (121) shows the lowest value. ENTRY 27 (177.800) shows the greatest value while ENTRY 48 (79.6) shows the minimum value in the fourth development stage.

Area Under Chlorophyll Index Progress Curve (AUCIPC) was calculated using Rosyara *et al*., (2007) technique to assess the pace of reduction in CI value. Genotype ENTRY 1 (2828.75) provided the highest AUCIPC value, whereas genotype ENTRY 37 (1,867.57) produced the lowest (Table 4). A high AUCIPC suggests that more chlorophyll is retained at maturity. Consequently, genotypes like ENTRY 1, 8, 19, 27, 28, and 29 have excellent chlorophyll efficiency at maturity. Rosyara *et al*., (2010) reported a similar result when chlorophyll content was assessed using SPAD reading and the AUSDC (Area Under SPAD Decline Curve) value was found to be significantly different across genotypes following anthesis.

Table 4. AUCIPC values pertaining to different genotypes under-study

Genotype	AUCIPC 1	AUCIPC 2	AUCIPC 3	Mean AUCIPC
1	3,806.65	3,288.80	1,390.80	2,828.75
2	3,359.20	2,728.80	1,054.00	2,380.67
3	3,476.05	2,796.80	946.8	2,406.55
4	3,549.20	2,640.80	939.2	2,376.40
5	2,652.40	2,217.60	906.8	1,925.60
6	3,329.75	2,404.00	854	2,195.92
7	3,083.70	2,439.20	980	2,167.64
8	3,711.65	2,815.20	1,131.20	2,552.68
9	3,469.40	2,641.60	1,091.60	2,400.87
10	3,837.05	2,373.60	875.2	2,361.95
11	3,591.00	2,709.60	1,058.40	2,453.00
12	3,328.80	2,651.20	1,018.40	2,332.80
13	3,179.65	2,280.80	850	2,103.49
14	3,448.50	2,595.20	1,124.00	2,389.24
15	3,210.05	2,416.00	1,004.80	2,210.28
16	3,458.00	2,811.20	984	2,417.74
17	3,511.20	2,541.60	1,076.80	2,376.54
18	2,943.10	2,336.00	1,006.80	2,095.30
19	3,857.95	2,850.40	998.8	2,569.05
20	3,285.10	2,494.40	967.2	2,248.90
21	3,523.55	2,548.00	1,112.40	2,394.65
22	2,786.35	2,272.00	958.8	2,005.72
23	3,170.15	2,576.80	983.6	2,243.52
24	3,308.85	2,388.00	826.8	2,174.55

25	2,858.55	2,188.80	985.6	2,010.98
26	3,230.00	2,712.00	1,114.00	2,352.00
27	3,564.40	2,905.60	1,324.80	2,598.27
28	3,534.00	2,978.40	1,344.00	2,618.80
29	3,745.85	2,989.60	1,153.60	2,629.68
30	3,021.95	2,340.80	1,005.20	2,122.65
31	2,850.95	2,226.40	874.8	1,984.05
32	3,547.30	2,532.80	986.8	2,355.64
33	2,896.55	2,454.40	1,025.20	2,125.38
34	3,294.60	2,484.80	1,004.80	2,261.40
35	3,529.25	2,618.40	928	2,358.55
36	3,287.00	2,731.20	1,266.80	2,428.34
37	2,631.50	2,060.00	911.2	1,867.57
38	3,235.70	2,474.40	876.8	2,195.64
39	3,181.55	2,756.00	1,202.00	2,379.85
40	3,224.30	2,453.60	921.2	2,199.70
41	2,912.70	2,328.80	1,026.40	2,089.30
42	2,970.65	2,223.20	948	2,047.28
43	3,713.55	2,554.40	920.4	2,396.12
44	2,983.00	2,513.60	1,051.60	2,182.73
45	3,053.30	2,269.60	932.8	2,085.24
46	2,956.40	2,509.60	1,037.20	2,167.73
47	2,855.70	2,257.60	878.8	1,997.37
48	2,902.25	2,137.60	802.4	1,947.42
49	2,977.30	2,184.00	868	2,009.77
50	3,307.90	2,441.60	858.4	2,202.63
SE(m)	382.2	338.3	101.5	245.4
L.S.D. (0.05)	1086.2	961.4	288.3	697.3

Canopy temperature depression

Canopy Temperature Depression was tested at two distinct development phases and found to be significantly different. Genotypes and genotype x growth stage interactions, on the other hand, were found to be non-significant (Table 5). The mean CTD values (Table 6) showed a steady drop in CTD as growth stages progressed in most genotypes, with the exception of 13 genotypes (ENTRY 5, 8, 14, 18, 20, 21, 24, 28, 34, 35, 46, 48, and 49), where CTD rose as growth stages progressed. This revealed that these genotypes had high physiological efficiency in the current environment.CTD values for several genotypes, such as ENTRY 1, 2, 6, 10, 15, 17, 22, 37, 39, 41, 42, 43, and 45, even became negative later on. In both development phases, one genotype (ENTRY 39) exhibited negative results (-0.050 in 68 DAS and -0.270 in 93 DAS). This might be due to a high canopy temperature caused by a lack of water in the plant or a lack of physiological efficiency. Earlier researchers, such as Guendouz *et al*., (2012) reported similar results using 10 durum wheat types to indicate CTD as a drought tolerance indicator in semi-arid settings.

Table 5. Two-way Analysis of variance of canopy temperature depression under different growth stages

Source of variation	df	Mean sum of square
Genotype	49	1.064
Growth stage	1	20.840***
Genotype x Growth stage	49	0.929
Error	199	1.140

*** $p<0.001$

Table 6. Two-way mean table for canopy temperature depression under different growth stages

GENOTYPE	68 DAS	93 DAS
1	1.860	-0.220
2	1.750	-0.120
3	1.140	0.600

4	0.800	0.440
5	0.350	1.020
6	2.070	-0.130
7	1.060	0.810
8	0.680	2.480
9	2.080	0.130
10	1.680	-0.700
11	2.050	0.600
12	0.640	0.140
13	1.830	0.360
14	1.170	1.370
15	2.050	-0.120
16	1.160	0.640
17	0.660	-0.330
18	1.170	1.650
19	1.540	0.230
20	0.640	0.900
21	0.920	1.060
22	1.710	-0.660
23	1.350	0.630
24	0.720	1.480
25	1.130	0.830
26	2.320	1.840
27	2.450	1.530
28	1.550	1.910
29	1.760	0.330
30	1.160	0.770
31	1.270	0.170
32	0.730	0.520
33	0.790	0.060
34	0.940	1.570
35	1.040	1.700
36	1.450	0.950
37	0.840	-0.320
38	1.600	0.300
39	-0.050	-0.270
40	1.030	0.080
41	0.830	-0.860
42	0.620	-1.370
43	0.900	-0.610
44	0.580	0.570
45	0.000	-0.310
46	0.120	0.660
47	1.340	0.980
48	0.170	0.540
49	0.190	0.510
50	1.160	0.380
Mean	1.140	0.494

Study on Spot blotch resistance

Spot blotch (*Bipolaris sorokiniana* (Sacc.) Shoem) scoring was done at four crop growth stages. The effects of genotype and development stages on disease severity % were shown to be very significant using analysis of variance (Table 7). There was no evidence of a significant interaction between genotype and development stages. The mean severity values across distinct development phases showed a progressive rise in severity as the growth stages progressed (Table 8). This is seen in spot blotch resistance, where the disease progresses fast as the crop matures, particularly in sensitive genotypes (Joshi *et al.*, 2007).

Table 7. Two-way Analysis of variance of disease severity under different growth stages

Source of variation	df	Mean sum of square
Genotype	49	405.65***
Growth stage	3	85734.72***
Genotype x Growth stage	147	66.88
Error	199	61.81

*** $p<0.001$

Table 8. Two-way mean table for disease severity under different growth stages

GENOTYPE	88 DAS	95 DAS	102 DAS	109 DAS
1	19.753	28.951	50.556	63.889
2	25.185	42.963	72.901	97.222
3	36.790	41.049	69.877	88.333
4	35.123	42.469	67.901	95.556
5	29.630	44.938	67.099	96.111
6	28.704	42.160	81.790	96.667
7	34.753	38.025	62.531	95.000
8	19.691	33.704	77.284	94.444
9	18.086	28.889	61.790	88.333
10	27.778	47.531	71.481	92.778
11	19.321	34.506	71.358	93.889
12	19.691	27.407	58.765	86.111
13	24.383	41.358	56.358	94.444
14	34.198	40.864	58.704	87.778
15	26.235	31.728	76.667	95.556
16	32.003	48.951	73.889	92.222
17	31.790	48.889	91.728	93.889
18	34.877	42.840	63.210	93.333
19	32.099	47.531	85.494	96.667
20	28.333	45.370	85.000	97.222
21	25.988	24.074	60.432	77.222
22	35.494	54.444	83.889	97.222
23	26.235	35.309	71.605	95.556
24	22.901	19.753	62.531	88.889
25	27.716	29.198	77.963	88.889
26	38.642	41.605	77.346	93.333
27	26.914	39.383	71.667	94.444
28	22.222	32.037	70.864	88.333
29	21.296	28.148	51.667	78.333
30	30.741	48.889	88.333	99.444
31	30.309	56.790	79.444	96.667
32	33.395	49.506	81.420	95.000
33	25.556	47.901	73.333	97.222
34	33.457	41.790	81.111	95.556
35	40.247	57.284	95.556	99.444
36	21.420	26.358	75.617	85.000
37	36.728	48.148	91.111	98.889
38	44.259	49.630	81.667	95.000
39	19.938	30.617	56.481	79.444
40	27.716	41.235	90.000	98.333
41	36.728	43.086	78.704	93.333
42	37.840	41.790	80.247	93.889
43	24.012	44.444	98.889	100.000

44	27.160	41.975	61.235	84.444
45	30.926	37.346	70.741	92.778
46	33.889	46.173	84.444	98.333
47	25.617	34.383	73.889	90.000
48	33.889	52.037	71.111	96.667
49	35.432	44.630	88.765	95.000
50	30.247	59.136	93.025	99.444
Mean	29.307	40.944	74.549	92.511

AUDPC values were determined for each genotype to determine disease progression and growth phases. The mean values of AUDPC are shown in Table 9. ENTRY 35 (341.36) represents the greatest value in AUDPC 1 values, whereas ENTRY 24 represents the minimum value (149.29). ENTRY 35 (534.94) has the highest value in AUDPC 2, while ENTRY 1 has the lowest (278.27). ENTRY 43 (696.11) in AUDPC 3 displays the greatest value, whereas ENTRY 1 displays the minimum (400.555). The greatest value in the Mean AUDPC values is represented by ENTRY 35 (519.595), while the smallest value is given by ENTRTY 1 (283.095).There were 29 highly susceptible (HS) genotypes, 14 susceptible to highly susceptible (S-HS) genotypes, and 06 susceptible genotypes (S). Only one genotype, ENTRY 1, was moderately susceptible to susceptible (MS-S), and that genotype was a local check variety, DBW 187. It showed that all of the germplasm in the nursery was classified as either highly susceptible or susceptible. As a result, no genotype could be chosen in terms of disease resistance.

Table 9. AUDPC values pertaining to different genotypes under study

Genotype	AUDPC 1	AUDPC 2	AUDPC 3	Mean AUDPC	Resistance category
1	170.465	278.270	400.555	283.095	MS-S
2	238.515	405.525	595.430	413.160	HS
3	272.440	388.240	553.735	404.805	HS
4	271.575	386.300	572.100	409.990	HS
5	260.985	392.130	571.235	408.115	HS
6	248.025	433.825	624.595	435.485	HS
7	254.720	351.945	551.355	386.010	S-HS
8	186.885	388.455	601.050	392.130	S-HS
9	164.415	317.380	525.430	335.740	S
10	263.580	416.545	574.905	418.340	HS
11	188.395	370.525	578.360	379.095	S-HS
12	164.845	301.605	507.065	324.510	S
13	230.090	342.005	527.810	366.635	S-HS
14	262.715	348.485	512.685	374.630	S-HS
15	202.870	379.380	602.780	395.010	S-HS
16	283.335	429.940	581.390	431.555	HS
17	282.375	492.160	649.660	474.735	HS
18	272.005	371.170	547.905	397.025	S-HS
19	278.705	465.585	637.560	460.615	HS
20	257.965	456.295	637.780	450.680	HS
21	175.215	295.770	481.790	317.590	S
22	314.785	484.170	633.890	477.615	HS
23	215.405	374.200	585.060	391.555	S-HS

24	149.290	287.995	529.970	322.415	S
25	199.195	375.060	583.985	386.080	S-HS
26	280.865	416.330	597.375	431.525	HS
27	232.035	388.670	581.385	400.700	HS
28	189.905	360.155	557.190	369.085	S-HS
29	173.055	279.350	455.000	302.470	S
30	278.700	480.275	657.220	472.065	HS
31	304.845	476.820	616.390	466.020	HS
32	290.155	458.240	617.465	455.290	HS
33	257.095	424.320	596.945	426.120	HS
34	263.365	430.150	618.335	437.285	HS
35	341.360	534.940	682.500	519.595	HS
36	167.220	356.915	562.160	362.100	S-HS
37	297.070	487.405	665.000	483.155	HS
38	328.610	459.535	618.335	468.830	HS
39	176.945	304.850	475.740	319.175	S
40	241.325	459.320	659.170	453.270	HS
41	279.350	426.265	602.130	435.915	HS
42	278.705	427.130	609.475	438.440	HS
43	239.600	501.665	696.110	479.125	HS
44	241.975	361.235	509.875	371.030	S-HS
45	238.950	378.300	572.315	396.525	S-HS
46	280.215	457.160	639.720	459.035	HS
47	210.000	378.950	573.610	387.520	S-HS
48	300.740	431.020	587.225	439.660	HS
49	280.215	466.885	643.180	463.425	HS
50	312.840	532.565	673.645	506.345	HS
S.Em (±)	26.634	38.896	35.310	29.865	
L.S.D. (0.05)	75.693	110.541	100.349	84.871	

Correlation analysis

Correlation analysis in Table 10 showed, CTD, BY, and GY were all positively correlated with AUCIPC. CTD also had a positive relationship with AUCIPC and BY. This meant that when the AUCIPC value climbed, the genotypes' biomass increased as well, and canopy temperature reduced as a result of the high physiological efficiency. Khakwani *et al*., 2012 and Al-Ghzawi *et al*., 2018 reported similar results in wheat. AUDPC was shown to have a positive relationship with HI, but was found to have a negative relationship with AUCIPC and BY. This meant that a high chlorophyll index value was associated with a higher disease severity. This might be attributed to the loss of greenness that occurs during periods of significant disease infestation. Rosyara *et al*., 2007, Rosyara *et al*., 2010, obtained similar results.

Table 10. Correlation matrix between 7 characters of wheat

Traits	AUCIPC	CTD	AUDPC	TGW	BY	GY	HI
AUCIPC	1						
CTD	0.294**	1					
AUDPC	-0.262**	-0.021	1				
TGW	0.04	-0.074	0.029	1			
BY	0.402**	0.239*	-0.382**	-0.165	1		
GY	0.217*	0.144	-0.166	-0.103	0.477**	1	
HI	-0.173	-0.09	0.202*	0.053	-0.473**	0.515**	1

*$p<0.05$, **$p<0.01$, AUCIPC= Area Under Chlorophyll Index Progress Curve, CTD= Canopy Temperature Depression, AUDPC=Area Under Disease Progression Curve, TGW= 1000 Grain Weight (g), BM= Biological Yield (t^{-ha}), GY= Grain Yield (t^{-ha}), HI= Harvest Index

CONCLUSION

A substantial difference was found across growth stages for chlorophyll index, canopy temperature depression, and spot blotch in the genotypes. ENTRY 8 and 28 could be used for drought tolerance breeding as only they showed excellent chlorophyll efficiency at maturity and high physiological efficiency in the current environment. No genotypes used in the study could be recommended for disease resistance breeding. Correlation analysis concludes that as the AUCIPC value increases, biomass increases, canopy temperature falls resulting in high physiological efficiency. Moreover, high chlorophyll index values are associated with high disease severity.

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Conflict of interest

The authors have declared no conflict of interests exist.

Data Availability Statement

Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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