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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 64-70

www.thepharmajournal.com
Received: 19-10-2022
Accepted: 19-12-2022

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Turcicum leaf blight (TLB) resistance in field corn: Screening of early generation segregating lines coupled with higher productivity

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Abstract
Maize is one of the staple food crops globally and is affected by more than 61 diseases and of them 16 diseases are adversely affecting this crop. One among them is Turcicum (TLB) or northern corn leaf blight (NCLB) caused by the ascomycetes fungi *Exserohilum turcicum*. In India, the loss in grain yield due to TLB ranges from 25 to 90% depending on the disease severity. Early testing is one of the breeding methods advocated in maize breeding. An elite composite ADC-1 was selected for generating early segregating generations (selfed generations). One hundred S_1s were evaluated against TLB under artificial epiphytotics and for grain yield during *kharif* 2020. The spreader rows were planted at regular intervals to ensure buildup of sufficient TLB inoculums. The susceptible check, exhibited the disease score of 8, indicating the sufficiency of inoculums during the screening phase. Out of these, 30 lines were selected based on TLB reaction and grain yield and selfed to produce S_2s. These 30 lines along with checks were evaluated in randomized block design (RBD) during *Kharif* 2021. Among the thirty S_1 lines, 24 lines belonged to moderately resistant group and six lines were moderately susceptible. The lines S_1-23 (11.22 t/ha), S_1-32 (11.12 t/ha) and S_1-49 (10.84 t/ha) recorded highest grain yield with moderate resistance. Whereas, among the 30 S_2 lines, one line, S_2-3 recorded resistant reaction, while, 17 lines were moderately resistant and 12 moderately susceptible. The lines, S_2-55 (10.29 t/ha), S_2-74 (9.61 t/ha) and S_2-47 (9.33 t/ha) recorded highest grain yield with moderate resistance. There was a discernible decrease in yield from S_1 (8.28 t/ha) to S_2 (6.69 t/ha) generation. This was expected in allogamous crop like maize as a consequence of inbreeding. Among the potential top ten S_2 lines, S_2-55, S_2-23 and S_2-26 were also listed under potential top ten S_1 lines with moderately resistant reaction. This indicated the consistency of the lines over the selfing generation. Hence, there is further scope for selection and improvement of TLB and grain yield by accumulation of favourable alleles. Thus, the results suggested the possibility of improving resistance against TLB and grain yield further through population improvement approach, preferably by recurrent selection.

Keywords: Maize, northern corn leaf blight, resistance, selfed generation, turcicum leaf blight

Introduction

Maize is one of the staple food crops in the world. Globally, it ranks third, next to wheat and husked rice, in production covering nearly 22% of the world area. The suitability of maize to diverse environments is unmatched by any other crop as it has wide range of plasticity. Hence maize is known as "queen of cereals". By origin maize is native to Central America (Mexico). It is a tropical crop and has adapted magnificently to temperate environments with much higher productivity.

Maize (*Zea mays* L.) is cultivated in 170 countries all over the world. Globally, it occupies 193.7 mha area with a production of 1147.7 mt and productivity of 5.75 tha^{-1} (Anon, 2020) [2]. The top 5 countries are USA, China, Brazil, Argentina, and Ukraine which account for 75.18% of the total world maize production. India ranks 4th in area (9.89 mha) and 7th in production (31.65 mt), representing around 4% of the world maize area and 2% of total production (Anon, 2021) [3].

Maize is affected by about 61 diseases and 16 out of them are adversely affecting this crop and have been identified as major ones. Among the diseases of maize, foliar diseases occupy a significant position and are the important factors reducing the yield and quality of maize produce. One among them is Turcicum (TLB) or northern corn leaf blight (NCLB) caused by the ascomycetes fungi, *Exserohilum turcicum* Pass. It is a ubiquitous foliar disease of maize causing significant yield loss.

Maize grain yield loss varies from 25 to 90% in different parts of India depending upon the severity of TLB epiphytotics (Chenulu and Hora, 1962) [5]. The region with assured rainfall during crop growing season will experience relatively low temperature, cloudy weather, high humidity and heavy dew on the plant. These provide very congenial conditions for severe disease occurrence (Singh *et al*., 2004) [17]. In India, this disease is prevalent in the states of Karnataka, Himachal Pradesh, Uttarakhand, Orissa, Andhra Pradesh and North Eastern Hill states. In Karnataka, TLB is endemic to Dharwad, parts of Belgaum, Mysore, Bangalore, Tumkur and Kolar districts and are regarded as 'Hot spots' of the disease (Harlapur *et al*., 2008) [7].

Though, the TLB disease can be managed by chemicals and crop husbandry practices, the most appropriate and economical strategy is to exploit host plant resistance. The resistant varieties are not only environment friendly but also convenient to adopt at farmer's level. Since new races of pathogens will be emerging continuously and some resistance sources may become susceptible; there is a need to identify new sources of resistance through artificial epiphytotics year after year to cater to the resistance breeding programme. With these facts in mind, the present study was carried out to screen and identify the early segregating lines of maize for resistance to TLB coupled with higher productivity. The paper identified TLB resistant lines and moderately resistant lines, those can either be used as sources of resistance or would be utilized for further improvement of maize populations and derivation of improved inbreds through population improvement programmes.

Material and Methods

In the present experiment, ADC 1 composite, developed at ICAR-IARI's Regional Research Centre, Dharwad by compositing 7 elite inbred lines that produced heterotic hybrids, was used as the base material (Table 1). The composite is being maintained by bulk pollination/sibbing. It has wide variability with respect to grain yield and TLB disease resistance. The TLB score of ADC 1 varied from 3 to 8 on a scale of 1 to 9 in different individuals and yield per plant ranged from 65.40 g to 210.60 g. During *Spring* 2020, 450 ADC 1 (S_0) plants were selfed to produce S_1's; Based on the cob parameters, 100 S_1 lines were selected and evaluated for TLB, yield and yield related attributes along with susceptible check (Early composite) and base population under artificial epiphytotic conditions during *kharif* 2020. Based on *kharif* 2020 data for TLB and yield, top 30 S_1s were selected and advanced to S_2 generation. During *kharif* 2021, 30 S_2 lines along with susceptible check and base population were evaluated for TLB and yield perse under artificial epiphytotic conditions.

Table 1: Experimental material used for the experiment

Sl. No.	Material used	Name	Pedigree	Source
1	Composite population	ADC-1	PM-6, PM-37, PM-46, PM-54, PM-58, PM- 57 and PM-93.	ICAR-IARI's Regional Research Centre, Dharwad
2	Early segregating generations	S_1 and S_2	ADC-1	ICAR-IARI's Regional Research Centre, Dharwad
3	Spreader	Early composite	Susceptible Check	AICRP on Maize Dharwad

The segregating lines, check (Early composite) and base population were sown in the field in RCBD with two replications during two consecutive *kharif* seasons (2020 and 2021) at Botanical Garden, Department of Genetics and Plant Breeding, College of Agriculture, Dharwad, Karnataka, India. Each entry was sown in two rows of 3 m length with a spacing of 60 x 20 cm in each replication. All the package of practices as recommended by University of Agricultural Sciences, Dharwad, were followed at appropriate times to raise a healthy crop in each season. Observations were recorded on five randomly selected plants from each entry for nine characters, *viz.*, days to 50% tasseling, days to 50% silking, turcicum leaf blight (TLB), plant height, cob girth, cob length, 100 seed weight, shelling% and grain yield. The artificial epiphytotics of TLB were created by following the standard artificial inoculation technique.

Creation of artificial epiphytotics

The turcicum leaf blight (TLB) pathogen (*E. turcicum*) was isolated from the blighted maize leaves collected from two different maize fields at Dharwad. The blighted leaf tissue, showing typical symptoms of TLB, was cut into small pieces and was surface sterilized by treating with 0.1% mercuric chloride ($HgCl_2$). The sterilized leaf pieces were washed three times in sterile double distilled water and dried on sterile filter paper. These tissue pieces were inoculated onto petri-plates containing sterilized agar media. The plates were incubated at 24± 2 °C for 7 days. The well-developed fungal colonies were inoculated on PDA slants and incubated. Colonies showing typical features of *E. turcicum* maintained on PDA slants were mass multiplied on sterile (autoclaved twice) and sucrose treated sorghum kernels in flasks The mass multiplication of the pathogen *Exserohilum turcicum* Pass. Was carried out as per the procedure of Joshi *et al*., (1969) [10] (Plate 1). One hundred grams of sorghum grains were placed in 50 conical flasks of 500 ml each and soaked in tap water for one day and night. Excess water was drained off and the material was subjected to autoclaved twice at the rate of 1.10 kg per cm^2 pressure for one hour at an interval of 24 hours. The contents of the flasks were thoroughly shaken after sterilization to prevent clumping. The flasks were aseptically inoculated with *Exserohilum turcicum* Pass. Culture and incubated at 27 °C ± 1 °C for 20 days and the flasks were shaken every alternate day to avoid clumping. Over three weeks, the sorghum grains were covered with black mycelia growth and conidia of the fungus colonized sorghum grains. The fully colonized sporulated sorghum grain culture was used for creating artificial epiphytotic conditions in the field. To ensure sufficient disease infection, all the plants were subjected to artificial inoculation by following leaf whorl method of application at 40, 50 and 60 days after sowing (DAS) during evening hours and a water spray was also taken up to provide necessary humidity for germination of conidia. In addition to artificial inoculation as a source for disease epidemic, highly susceptible line *viz.*, Early composite, was grown as spreader/infector row (two rows of Early composite after every ten rows of study material). Disease scoring was done according to 1-9 scale developed by Indian Institute of Maize Research, Ludhiana (Anon., 2014) [1]. Observations were recorded before silk drying stage and at silk drying stage. Disease scores were used to estimate percent disease index (PDI) using the following formula given by Wheeler (1969) [19].

$$PDI = \frac{\text{Sum of individual disease score}}{\text{Total number of plants scored} \times \text{Maximum disease score}} \times 100$$

Experimental results and discussion

Evaluation of S_1 lines for TLB, yield and yield attributes

The wide range of variability was observed among the segregating S_1 lines and the results are presented below.

Turcicum leaf blight

TLB disease is one of the major biotic production constraints in maize. Among other disease management practices, host plant resistance is considered as most practical, feasible and economical method. Development and identification of resistance sources is the first step in breeding for TLB resistance. Screening of lines under artificial epiphytotics enables the identification of resistant sources.

In our study, the spreader rows of susceptible check recorded PDI of 85.89% with a disease score of 8 implying their highly susceptible reaction to TLB. The spreader rows were repeated after every five test entries (10 rows) and very severe disease infection to spreader rows ensured buildup of sufficient inoculum load in the experimental plots during screening against TLB. Among the selected 30 S_1 lines, PDI ranged from 37.56 (S_1-1) to 64.39 (S_1-23) percent with a disease score of 4 and 7, respectively and with an overall mean PDI of 50.99% (Table 3). Out of 30 S_1 lines, 24 lines belong to moderately resistant group and 6 belong to moderately susceptible group. The S_1 lines, S_1-1 (37.56%), S_1-49 (38.56%) and S_1-17 (42.84%) topped for TLB reaction and base population recorded PDI of 54.83% with a disease score of 5. The higher frequency of moderately resistant lines among selected 30 S_1 lines is due to the fact that the genes governing the resistance are still segregating for the trait and due to stringency of selection. The same range of PDI results were reported by earlier researcher *viz*., Jenkins *et al.* (1954) [9], Pandurangegowda *et al*. (2002) [13] and Saleem *et al.* (2007) [16].

Table 2: Disease scale for turcicum leaf blight (TLB) in maize

Rating Scale	Degree of infection (percent DLA)	Disease reaction
1.0	Nil to very slight infection (< 10%)	
2.0	Slight infection, a few lesions scattered on two lower leaves (10.1-20%).	Resistant (R) (Score: ≤ 3.0) (PDI: ≤ 33.33)
3.0	Light infection, moderate number of lesions scattered on four lower leaves (20.1-30%).	
4.0	Light infection, moderate number of lesions scattered on lower leaves, a few lesions scattered on middle leaves below the cob (30.1-40%).	Moderately resistant (MR) (Score: 3.1–5.0) (PDI: 33.34-55.55)
5.0	Moderate infection, abundant number of lesions scattered on lower leaves, moderate number of lesions scattered on middle leaves below the cob (40.1-50%).	
6.0	Heavy infection, abundant number of lesions scattered on lower leaves, moderate infection on middle leaves and a few lesions on two leaves above the cob (50.1-60%).	Mod. susceptible (MS) (Score: 5.1-7.0) (PDI: 55.56-77.77)
7.0	Heavy infection, abundant number of lesions scattered on lower and middle leaves and moderate number of lesions on two to four leaves above the cob (60.1-70%).	
8.0	Very heavy infection, lesions abundant scattered on lower and middle leaves and spreading up to the flag leaf (70.1-80%).	Susceptible (S) (Score: >7.0) (PDI: >77.77)
9.0	Very heavy infection, lesions abundant scattered on almost all the leaves, plant prematurely dried and killed (>80%).	

Plate 1: Artificial culture of inoculum and artificial inoculation of *Exserohilum turcium*

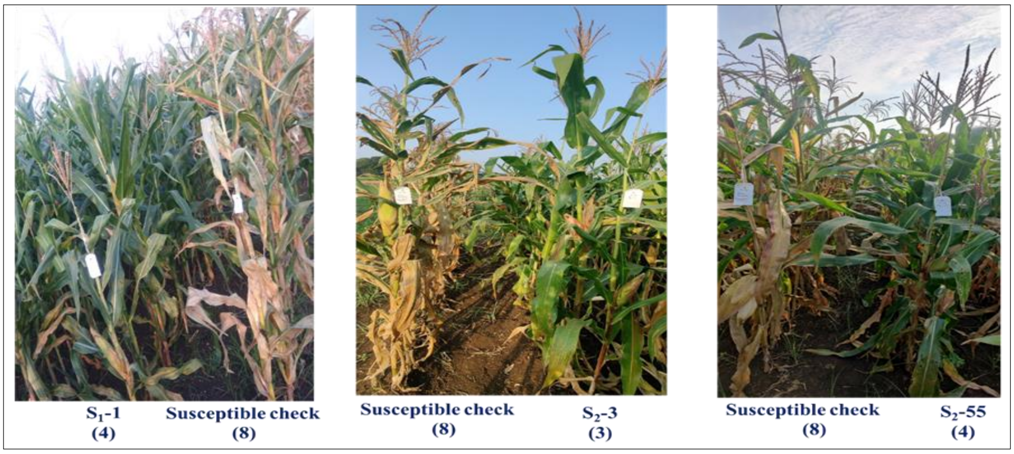

Plate 2: Disease reaction of representative potential early segregating lines with susceptible check

Table 3: Per se performance of derived S_1 lines for TLB, yield and yield related attributes

Sl. No.	S_1 line	Days to 50% Tasselling	Days to 50% Silking	Plant height (cm)	Cob length (cm)	Cob girth (cm)	100 Seed weight (g)	Shelling %	PDI (%)	TLB score	Grain yield (t/ha)
1	S_1-1	60	62	164.90	15.75	4.39	27.10	86.02	37.56	4	6.96
2	S_1-2	61	62	155.90	12.99	4.01	23.95	84.43	48.45	5	4.28
3	S_1-3	60	62	160.70	16.45	4.63	28.10	85.17	53.11	6	7.47
4	S_1-10	61	64	179.90	14.93	4.94	31.90	83.68	59.00	6	8.60
5	S_1-17	61	63	162.20	17.04	4.64	29.30	85.62	42.84	5	8.78
6	S_1-23	63	65	176.70	18.41	4.85	35.80	85.39	64.39	7	11.22
7	S_1-26	63	65	166.90	18.42	4.64	28.10	85.33	48.56	5	10.63
8	S_1-28	66	64	162.80	15.84	4.77	29.50	86.10	53.28	6	5.90
9	S_1-29	64	66	169.00	16.58	4.94	28.20	84.26	48.50	5	10.00
10	S_1-31	60	63	176.40	16.45	5.00	30.25	85.70	58.67	6	10.54
11	S_1-32	63	66	162.70	17.90	5.15	32.50	84.66	48.22	5	11.12
12	S_1-34	65	67	153.50	15.51	4.58	27.00	85.36	48.50	5	6.18
13	S_1-43	62	64	168.20	16.18	4.72	27.40	84.01	63.11	7	9.40
14	S_1-45	60	64	167.70	17.45	4.61	28.70	84.51	53.11	6	9.46
15	S_1-47	63	65	166.50	18.78	4.15	24.65	84.51	53.17	6	7.66
16	S_1-49	64	66	150.00	17.98	5.00	34.25	82.97	38.56	4	10.84
17	S_1-52	65	65	146.50	26.54	4.66	27.50	84.98	58.89	6	8.58
18	S_1-53	64	67	146.40	16.20	4.67	31.00	84.51	48.06	5	7.78
19	S_1-54	64	67	168.60	16.20	4.26	30.00	84.75	43.17	5	5.52
20	S_1-55	64	66	173.00	19.42	4.75	30.70	85.40	49.11	5	10.48
21	S_1-61	63	65	165.30	14.18	4.55	22.45	83.62	48.50	5	3.50
22	S_1-65	63	65	158.70	17.86	4.65	29.95	84.31	47.73	5	7.80
23	S_1-67	63	65	171.00	16.99	4.81	30.30	83.64	52.89	6	8.32
24	S_1-68	63	66	155.20	17.22	4.98	31.60	83.85	53.50	6	9.27
25	S_1-69	64	66	165.00	18.53	4.67	33.65	84.75	58.22	6	8.43
26	S_1-70	62	65	165.50	17.20	4.69	29.70	84.92	52.95	6	8.46
27	S_1-74	63	66	140.50	16.66	4.65	29.00	85.26	53.34	6	8.70
28	S_1-77	66	67	149.50	18.48	4.83	31.65	85.10	47.72	5	8.54
29	S_1-85	66	68	160.60	14.65	4.74	27.45	86.31	48.61	5	8.38
30	S_1-92	66	68	154.20	12.51	4.60	28.65	84.54	48.00	5	5.68
Mean		63	65	162.13	16.98	4.68	29.34	84.79	50.99	5	8.28
Max		66	68	179.90	26.54	5.15	35.80	86.31	64.39	7	11.22
Min		60	62	140.50	12.51	4.01	22.45	82.97	37.56	4	3.50
ADC1 (Base population) mean		64	66	152.64	14.75	4.37	29.58	83.73	54.83	5	7.08
Early composite		-	-	-	-	-	-	-	85.89	8	-
CV		3.77	4.22	9.35	12.40	3.70	7.33	1.79	11.85		16.82
SE		1.67	1.94	10.74	1.38	0.12	1.46	1.07	5.10		0.81
C.D. @ 5 %		4.68	5.45	21.52	3.86	0.33	4.10	2.66	12.86		2.29

Table 4: Per se performance of derived S_2 lines for TLB, yield and yield related attributes

Sl. No.	S_1 line	Days to 50% Tasselling	Days to 50% Silking	Plant height (cm)	Cob length (cm)	Cob girth (cm)	100 Seed weight (g)	Shelling %	PDI (%)	TLB score	Grain yield (t/ha)
1	S_2-1	61	64	170.00	11.00	3.94	23.60	86.22	36.45	4	4.38
2	S_2-2	62	65	189.07	14.89	4.00	28.30	86.76	42.89	5	7.94
3	S_2-3	60	63	178.20	13.19	4.46	31.10	83.14	32.12	3	9.02
4	S_2-10	59	65	187.78	13.00	4.60	31.40	85.91	47.56	5	8.39
5	S_2-17	59	62	198.99	12.71	4.06	25.65	84.93	58.67	6	6.55
6	S_2-23	60	63	174.58	14.77	4.37	32.80	86.25	42.78	5	8.39
7	S_2-26	60	62	193.06	13.44	4.38	30.50	81.54	47.78	5	8.24
8	S_2-28	61	64	195.00	14.00	4.66	27.60	82.97	47.67	5	7.47
9	S_2-29	61	63	189.81	12.16	4.69	24.40	83.05	42.45	5	5.73
10	S_2-31	58	61	195.34	14.66	4.30	26.45	83.08	59.22	6	6.33
11	S_2-32	60	64	168.91	14.83	4.78	24.60	82.81	42.11	5	6.16
12	S_2-34	60	62	153.66	10.87	4.34	27.60	81.82	47.78	5	5.10
13	S_2-43	60	64	170.73	13.39	3.84	27.20	82.15	58.56	6	4.81
14	S_2-45	59	63	135.24	12.71	3.71	26.55	80.86	47.33	5	4.80
15	S_2-47	60	62	170.28	16.30	4.34	25.60	86.82	58.89	6	9.33
16	S_2-49	61	65	153.66	10.54	4.59	28.10	82.89	58.78	6	6.27
17	S_2-52	62	64	187.38	12.74	4.00	24.50	76.71	63.78	7	5.23
18	S_2-53	61	63	180.26	16.20	4.42	28.80	83.72	58.67	6	7.97
19	S_2-54	63	65	150.48	14.16	3.96	27.05	82.13	69.33	7	4.90
20	S_2-55	62	64	207.11	16.60	4.68	27.25	86.17	36.33	4	10.29
21	S_2-61	62	65	162.36	11.10	4.12	21.55	77.75	47.33	4	3.50
22	S_2-65	60	62	185.18	16.59	4.22	25.85	77.78	58.56	5	7.09
23	S_2-67	63	66	187.11	15.28	4.40	27.90	84.21	58.89	3	7.85
24	S_2-68	63	65	189.12	12.16	4.32	28.70	72.13	58.67	5	4.92
25	S_2-69	60	62	179.19	16.49	4.52	33.00	80.93	53.45	6	9.31
26	S_2-70	60	65	182.16	15.40	3.78	22.40	79.57	52.89	5	6.17
27	S_2-74	62	63	151.69	18.13	4.40	31.50	84.21	64.11	5	9.61
28	S_2-77	63	64	168.44	12.59	4.00	21.60	81.87	47.45	5	4.70
29	S_2-85	61	64	154.05	13.10	4.40	25.90	79.37	47.56	5	5.51
30	S_2-92	62	64	161.37	12.79	4.16	25.35	76.24	47.67	6	4.66
Mean		61	63	175.67	13.86	4.28	27.09	82.13	51.19	5	6.69
Max		63	66	207.11	18.13	4.78	33.00	86.82	69.33	7	10.29
Min		58	61	135.24	10.54	3.71	21.55	72.13	32.12	3	3.50
ADC1 (Base population) mean		65	67	149.14	14.05	4.37	28.65	81.75	53.93	5	6.93
Early composite		-	-	-	-	-	-	-	86.52	8	-
CV		1.15	0.81	4.93	5.22	6.62	2.77	1.43	10.85		15.73
SE		0.46	0.34	5.83	0.43	0.18	0.43	0.84	5.00		0.39
C.D. @ 5 %		1.37	1.01	17.25	1.28	0.53	1.27	2.47	11.54		1.16

Yield and Plant characters

Grain yield is the most important and economic trait in maize; but is a complex quantitative trait that is influenced by several component characters and environmental factors. Comprehensive dissection of such traits is very difficult, but it is the ultimate goal in the majority of crop breeding programmes.

The grain yield in the present study ranged from 3.5 t/ha (S_1-61) to 11.22 t/ha (S_1-23). Among the early segregating S_1 lines S_1-23 (11.22 t/ha), S_1-32 (11.12 t/ha) and S_1-49 (10.84 t/ha) recorded highest grain yield. Overall mean of selected 30 S_1 lines revealed higher mean value (8.46 t/ha) than base population (7.08 t/ha) for grain yield indicating that selection was effective in enhancing the grain yield of selected S_1 over base population.

Cob length has direct effect on grain yield, it influences the other yield attributes like kernel number and kernel weight. The cob length varied from 12.51 cm (S_1-92) to 26.54 cm (S_1-52) with an overall mean of 16.98 cm. Cob girth is positively associated with grain yield, selecting for it could result in a significant increase in grain yield. The line S_1-2 (4.01 cm) registered lowest and line S_1-32 (5.15 cm) displayed highest cob girth with an overall mean of 4.68 cm. Grain yield of a plant is also determined by 100 grain weight, and thus 100 grain weight deserves consideration as one of the grain yield components. The line S_1-61 (22.45 g) registered lowest and line S_1-23 (35.80 g) displayed highest means for 100 seed weight with an overall mean of 29.34 g. Shelling percentage is the most important contributing trait towards grain yield. The mean shelling percentage among the lines ranged from 82.97% (S_1-49) to 86.31% (S_1-85) with an overall mean of 84.79%. Plant height is an important character, reduced plant confers lodging resistance. Reduced height is desirable in this context; The trade-off between high yield and lodging resistance is contradictory as plant height is positively correlated with grain yield. Therefore, it is important to strike a balance between high yield and lodging resistance. The mean plant height among the 30 lines ranged from 140.50 cm (S_1-74) to 179.90 cm (S_1-10) with an overall mean of 162.13 cm.

Among the early segregating S_1 lines S_1-23 (11.22 t/ha), S_1-32 (11.12 t/ha) and S_1-49 (10.84 t/ha) recorded highest grain yield and S_1-32 recorded highest in majority of the yield attributes too. These lines can be used in further breeding activities. The results for yield and its attributes are in agreement with the findings of Saleem *et al.* (2007) [16], Chandana (2013) [4], Mani (2017) [11], Vinod (2020) [18].

Maturity characters

Maturity trait is an important trait of a genotype that influences economic yield either directly or indirectly. The maturity of a genotype is defined by its components such as days to 50% tasseling and days to 50% silking (Gieshercht, 1960) [6]. The S_1 lines values for Days to 50% tasseling ranged from 60 (S_1-1) to 66 (S_1-28) days. The top three lines found earliest for the trait were S_1-1 (60 days), S_1-3 (60 days) and S_1-31 (60 days) with an overall mean of 63 days. Overall mean for the lines indicated that they are earlier than base population (65 days) for tasseling. The lines S_1-1 (62 days), S_1-2 (62 days) and S_1-3 (62 days) registered earliest and the line S_1-85 (68 days) displayed late silking with an overall mean of 65 days to 50% silking. These lines can be used as source for breeding for early maturity. The results are in agreement with the findings of Premlatha and Kalamani (2009) [15], Patil *et al*. (2020) [14], Vinod (2020) [18] and Mukhlif and Ramadan (2021) [12].

Evaluation of S_2 lines for TLB, yield and yield attributes

The early segregating S_2 lines recorded wide range of variability among them and the results are presented below.

Turcicum leaf blight

The spreader rows of susceptible check recorded PDI of 86.52% with a disease score of 8 (susceptible reaction) implying that high disease pressure was created in the experimental plots and that provided an ideal condition for screening the S_2 lines. PDI for 30 S_2 lines ranged between 32.12 (S_2-3) and 69.33 (S_2-54) percent (Table 4) with a disease score of 3 and 7, respectively and with an overall mean of 51.19%. Among the 30 S_2 lines, one line, S_2-3 recorded the least PDI of 32.12% with a TLB score of 3 and hence was resistant, while, 17 lines were moderately resistant and 12 moderately susceptible indicating the possibility of accumulation of favourable alleles and few lines with desirable TLB reaction could be developed. and base population recorded PDI of 53.93% with a disease score of 5. The earlier researchers *viz*., Jenkins *et al.* (1954) [9], Pandurangegowda *et al*. (2002) [13] and Saleem *et al.* (2007) [16] were also recorded PDI in the same range.

Yield and Plant characters

The grain yield ranged from 3.50 t/ha (S_2-61) to 10.29 t/ha (S_2-55). Some of the notable lines for the trait were, S_2-55 (10.29 t/ha), S_2-74 (9.61 t/ha) and S_2-47 (9.33 t/ha) with an overall mean of 6.69 t/ha.

The cob length varied from 10.54 cm (S_2-49) to 18.13 cm (S_2-74) with an overall mean of 13.86 cm. The line S_2-45 (3.71 cm) registered lowest and line S_2-32 (4.78 cm) displayed highest means for cob girth with an overall mean of 4.28 cm. The line S_2-61 (21.55 g) registered lowest and line S_2-69 (33.00 g) displayed highest means for 100 seed weight with an overall mean of 27.09 g. The mean shelling percentage among the S_2 lines ranged from 72.13% (S_2-68) to 86.82% (S_2-47) with an overall mean of 82.13%. The Plant height showed variation among the 30 S_2 lines ranging from 135.25 cm (S_2-45) to 207.11 cm (S_2-55) with an overall mean of 175.67 cm.

Overall mean of 30 S_2 lines revealed lower mean value (6.69 t/ha) than base population (6.93 t/ha) for grain yield due to inbreeding depression. The lines S_2-55 (10.29 t/ha), S_2-74 (9.61 t/ha) and S_2-47 (9.33 t/ha) were the potential lines among S_2 lines can be used in further breeding programme. The results for yield and its attributes are in agreement with the findings of Saleem *et al.* (2007) [16], Chandana (2013) [4], Mani (2017) [11] and Vinod (2020) [18].

Maturity characters

Among the S_2 lines, the mean values for days to 50% tasseling varied from 58 (S_2-31) to 63 (S_2-67) days with an overall mean of 61 days. The line S_2-31 (61 days) registered earliest and line S_2-67 (66 days) displayed late silking with an overall mean of 63 days to 50% silking. The results are in agreement with the findings of Premlatha and Kalamani (2009) [15], Patil *et al*. (2020) [14], Vinod (2020) [18] and Mukhlif and Ramadan (2021) [12].

The present study revealed that the S_1 lines, S_1-1 (37.56%), S_1-49 (38.56%) and S_1-17 (42.84%) were top three TLB lines with moderate resistance whereas S_1-23 (11.22 t/ha), S_1-32 (11.12 t/ha) and S_1-49 (10.84 t/ha) have shown potential yield and yield attributes with moderate TLB resistance. These lines could be to utilized as a source of TLB in further breeding programme. Base on the overall results the S_2 lines, S_2-3 (32.12%) TLB line with resistant reaction can be used as resistant sources, whereas S_2-55 (10.29 t/ha), S_2-74 (9.61 t/ha) and S_2-47 (9.33 t/ha) were the potential lines among S_2 lines with moderate TLB resistance. These lines could be to utilized in further breeding programme. Among the potential top ten S_2 lines *viz*., S_2-55, S_2-23 and S_2-26 were found common as a potential top ten S_1 lines with moderately resistant reaction indicated that the consistency of the lines over the selfing generation.

Conclusion

The resistant disease reaction number increased from S_1 lines to S_2 lines it indicated that the loci contributing towards resistance were going to be fixed over selfing generations. The resistant lines, S_2-3 can be used as resistant source for TLB for further resistant breeding in maize. Whereas, mean performance with respect to grain yield got reduced drastically from S_1s to S_2s because of inbreeding depression (Jenkins, 1935). Among the potential top ten S_2 lines *viz*., S_2-55, S_2-23 and S_2-26 were also found in the top ten S_1 lines with moderately resistant reaction indicated that the consistency of the lines over the selfing generation. Hence, there is further scope for selection and improvement of TLB and grain yield even in early generations by accumulation of favourable alleles. Thus, the results suggested the possibility of improving resistance against TLB and grain yield further through population improvement approach, preferably by recurrent selection. However, the performance of these lines need to be evaluated in further segregating generations to confirm the effectiveness of early testing.

Acknowledgements

The authors are thankful to the Department of Genetics and Plant Breeding, Department of Plant Pathology, University of

Agricultural Sciences, Dharwad and ICAR-IARI's Regional Research Centre, Dharwad for providing facilities to conduct this research.

Statements and Declarations

Conflict of interest

The authors declare that they have no conflict of interest.

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