

Research Article



Study of Northern Corn Leaf Blight (NCLB) on Maize (*Zea mays* L.) Genotypes and its Effect on Yield

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Abstract | Northern leaf blight (NCLB) of maize is most infectious foliar disease in Himalayan region of the Asia, caused by fungus *Exerohillum turcicum*. We evaluated resistant genotypes against NCLB under agro-climatic condition of Rawalakot and assessed the yield loss due to impact of NCLB. Maize plants were artificially inoculated at four to six leaf stages. Thirty genotypes were screened in first field trail in June 2016. Genotypes had significant differences for NCLB severity and reactions and were classified into resistant, susceptible and moderate categories on the basis of 0-5 disease severity scale. The percent disease incidence ranged from 20-60% and area under disease progressive curve (AUDPC) 22-362dsu (Development stage unit). On the basis of disease rating scale and pathological traits, it was reported that three parental genotypes Karamat-Bar-25, SZP-13200, NCEV-1530-11 had lowest values for all pathological traits and severity rating of 5R, 5R and 10R and marked as highly resistant (R) genotypes, whereas three parental genotypes Soan-3, Ghuari-122, Kissan-60 were evaluated as highly susceptible (S) within germplasm and had highest values for pathological traits with severity rating of 90S, 90S and 80S respectively. In second field trail (June 2017) crosses were made between selected parental genotypes in order to get F₁ progeny and evaluation of F₁ progenies and their parents was done in June 2018 for morpho-pathological traits to assess the impact of NCLB on yield loss and yield related attributes. Results showed that area under disease progressive curve ranged 10-402dsu while disease incidence ranged 25 to 77% and showed negative correlation with grain yield and yield traits. Parents and their F₁ progenies indicated that there is improvement in new recombinants of selected parents for yield enhancement. The present study revealed the effectiveness of selection and hybridization for enhancement of resistance to NCLB and improvement of yield and yield associated traits and their utilization in future breeding program.

Received | February 08, 2018; **Accepted** | September 10, 2019; **Published** | November 12, 2019

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Citation | Razzaq, T., M.F. Khan and S.I. Awan. 2019. Study of northern corn leaf blight (NCLB) on maize (*Zea mays* L.) genotypes and its effect on yield. *Sarhad Journal of Agriculture*, 35(4): 1166-1174.

DOI | <http://dx.doi.org/10.17582/journal.sja/2019/35.4.1166.1174>

Keywords | Northern leaf blight, Incidence, Yield loss, Genotypes, Resistance

Introduction

Maize (*Zea mays* L.) is third most important crop after rice and wheat in Pakistan (Hussain et al., 2011) and it belongs to family *Poaceae*. Maize is a significant high yielding cereal crop in many countries like Pakistan, where rapidly growing population

needs more food and food supplies. In Pakistan, total cultivated cropped area is 4.8% and total agricultural output of maize is 3.5%. Its cultivation on an expected area of 0.9 million hectare with the annual production of 1.3 million tons (Pakistan Statistics, 2016). It is not only the important crop of Pakistan but is also a valuable crop of Azad Kashmir with plantation of

0.122 million hectare during Kharif season. It holds an irreplaceable position as feed, food and source of industrially essential products in the agricultural world. Maize breeders give contagious efforts to increase and improve the yielding ability of this crop. However, the sustainability of the maize production remains debatable due to existing biotic and abiotic stresses. Pakistan Himalayan states have been center of maize cultivation since long and contributing significantly to maize production as well demand. Some pathogens are identified as a serious causal agent of diseases in maize. The diseases caused by fungal pathogen are of great economic importance.

Northern corn leaf blight (NCLB) also known as *Turcicum* leaf blight of maize is major foliar disease and it's a problematic to maize farmers in highland of Himalayan region, worldwide. It is prevalent in maize growing zones and considered to be very important in terms of its geographical distribution and potential to cause yield losses. It can be serious in tropical area with mid-altitude where long cloudy weather, high humidity and relatively low temperature prevailing throughout the maize growing season. Yield losses can easily exceed 50% if the disease appears before flowering. However, the losses get reduced if infection takes place at a later stage (Singh, 2004). The blight starts from the lower leaves and spreads towards the developing ear and then flag leaf of the plant (CIMMYT, 2004). Most of the maize breeding programs initiated with the aim to improve disease resistant varieties with increases grain yield (GY), also consider other related traits i.e. plant height (PH), days to 50% silking (DFS), days to 50% tasseling (DFT), ear height (EH), and days to maturity (DTM). Since these traits are also used in diseases management.

Planting resistant varieties is the most effective, economically and environmentally safe method for sustainable disease control. Slow disease development is characterized by several components like low area under the disease progress curve, least disease incidence, smaller lesion size and less lesion number (Bashyal et al., 2011).

Northern blight is an important foliar disease of maize in the Himalayan region particularly in Rawalakot, Azad Kashmir. The disease become epidemic due to the environmental factors i.e. high humidity, frequent rain falls and low temperature. The climate of this area favors the endemic of NCLB and causes serious

economic loss. The new sources of NCLB resistance identified in the present study will be helpful for their utilization in future breeding programs and ultimately helpful for the evaluation of resistant genotypes in maize crop.

Materials and Methods

The current experiment was conducted at experimental field of University of Poonch Rawalakot (Latitude 33°51'32.18"N, Longitude 73° 45'34.93"E, Elevation 5500 ft) during 2016-2018. Complete randomized block design (RCBD) was used for the study with three replications. The seeds were sown in well and fine prepared soil with plant to plant distance of 25 cm and row to row distance of 75 cm. Recommended dose of fertilizers (NPK and Urea) were applied during seed bed preparation. Thirty genotypes were screened under artificial epiphytotic condition of NCLB. Selection was done on the basis of disease assessment traits and yield related attributes and F_1 progeny was obtained during the study period (2016).

Inoculum preparation and inoculation

Collection of diseased plant's sample (leaves) was done during fall 2015 from natural maize field at harvest stage. The sample were put in sunlight to dry and shifted to an oven for 48 hrs at 40 °C. After oven drying, samples were homogenized using grinder, in order to make inoculum in fine powder form (Ali et al., 2014). The powder was well-sealed and kept for artificial inoculation for the subsequent season. At the evening, 0.5g inoculum was manually dropped in leaves whorls at seedling stage with the interval of one week (Khalil et al., 2010; Ali et al., 2012).

Preparation of genetic material (F_1 progeny production phase)

Improvement in maize germplasm of thirty genotypes has been initiated through selection breeding procedure on the basis of disease severity and yield related traits in June 2016. Genotypes Karamat-Bar-25, NCEV-1530-11 and SZP-13200 having least severity rating and showing high resistant reaction against NCLB whereas genotypes Soan-3, Kissan-60 and Ghuari-122 having high disease severity rating with high susceptible response against NCLB under artificial epiphytic field conditions.

Hybridization

The screened genotypes as highly resistant (Karamat-

Bar-25, NCEV-11, SZP-13200) and highly susceptible (Soan-3, Ghuari-122, Kissan-60) on the basis of their high and low NCLB incidence were crossed and ten plants per line were pollinated to obtained sufficient seed for sowing F_1 crop during 2017.

Cross pattern was according to line \times tester model

The line \times tester analysis was described by Kempthorne (1957) is one of the most powerful technique, available to assess the effects of various cross combination and helps in selection of desired parents for manipulation in breeding program Rashid et al. (2007), Jain et al. (2012). The crosses were harvested at physiological maturity and properly threshed seeds were used for rising F_1 generation.

Evaluation of F_1 single cross hybrids and their parents

An extreme cross between resistant and susceptible genotypes, having F_1 progeny along with parents were sown in summer 2018. Each genotype was planted in a separate plot having 5 meter row length and 75 apart in randomized complete block design. All the precautionary measures were adopted to avoid undesirable contamination of genetic material. Data was recorded for parameters in order to assess yield losses under the impact of NCLB.

Disease Assessment

Maize field trial was visually observed at two–three weeks after inoculation. Randomly ten plants were selected and tagged for disease assessments. Plants were rated and monitored with the interval of 10 days. Monitored plants were marked with the marker so that plants could be traced and monitored again. Data on following parameters were recorded.

Leaf disease incidence (LDI)

The percent leaf disease incidence was calculated using formula given by Ishfaq et al. (2014).

$$LDI(\%) = \frac{\text{number of infected leaves}}{\text{total number of leaves assessed}} \times 100$$

Area under disease progressive curve (AUDPC)

The diseased area (AUDPC) was calculated using formula as described by Madden and Campbell (1990).

$$AUDPC = \sum_{i=1}^{n-1} (y_i + y_{i+1}) (t_{i+1} - t_i) / 2$$

Where;

n- number of observations, ti- days after planting for the 1st disease assessment and yi is the disease severity.

Table 1: Screened resistant and susceptible parent genotypes used in the study for hybridization.

A	Resistant genotype (Karamat-Bar-25)
B	Resistant genotype (NCEV-11)
C	Resistant genotype (SZP-13200)
D	Susceptible genotype (Soan-3)
E	Susceptible genotype (Ghuari-122)
F	Susceptible genotype (Kissan-60)

Table 2: Cross pattern of the selected (parents) genotypes.

Taster A	Taster B	Taster C
A \times D	B \times D	C \times D
A \times E	B \times E	C \times E
A \times F	B \times F	C \times F

Reaction and scoring of Disease

The response of maize genotypes was recorded by following capital letters.

O: No visible infection; R: Resistant (Necrotic areas with no apparent infection, no uredia); MR: moderately resistant (Fewer uredia may appear and covered by necrotic areas); MS: moderately susceptible (Mediocre uredia presen witht no visible necrosis but feasibly of some chlorosis); S: Susceptible (huge number of uredia and minute or no chlorosis, appearance of severity).

All the leaves on infected plants were scored using 0-5 scale adopted by maize pathology unit (CIMMYT, 2004) as 0 - no lesion appear, 1- rare or few lesions spread on leaves covering 10% of leafy area, 2- lesions spread on leaf and covering up to 11- 25% area, 3- lesions covers up to 26-50% leaf area, 4- abundant lesions on leaf surface covering almost 51-75% area, 5- lesions spread on whole leaf and plant early dried covering 76-100% leaf area.

Yield attributes

Plant height was recorded from lower (ground) level to the base of tassel (after milking stages). Ear length was measured from the base to the tip of ear. Ear diameter was measured from the central part of the upper most ears as maximum diameter of the ear. Number of kernel per row was recorded as average number of kernel per rows of five respective ears. Number of kernel rows per ear was recorded in the

central part of the uppermost ear. Thousand grains were taken from the seed bulk and harvested for grain yield. Electric balanced was used to record the weight in grams. The total weight of grains per plant was taken after threshing them manually. Biological yield per plant was calculated using formula:

$$\text{Biological yield per plant} = \frac{\text{total yield per plant(ear + stalk)}}{\text{total number of plants}} \times 100$$

Statistical analysis

Data on Northern Corn Leaf Blight assessment were subjected to various statistical techniques. Mean separation was done based on the LSD at the 5% probability level. Simple statistics and numerical taxonomic techniques were utilized for cluster analysis with the help of computer software PAST (Hammer et al., 2001). Software SPSS. 20 was used to find out the correlation among the maize genotypes.

Results and Discussion

Leaf disease incidence (LDI)

Mean values for leaf disease incidence are presented in Table 3. Mean values range from 25-77%. Maximum mean percentage for LDI was shown by genotype Soan-3 (77%) followed by Ghuari (75%) and Kissan (64%). Whereas minimum mean percentage was shown by genotype SZP-13200 (25%), Karamat-Bar (28%) and NCEV-11 (30%). Crosses Kramat-Bar-25×Kissan-60 showed the LDI of 54%, Kramat-Bar-25×Ghuari-122 (41%), Kramat-Bar-25×Soan-3 (64%), SZP-13200×Kissan-60 (36%), SZP-13200×Ghuari-122 (50%), SZP-13200×Soan-3 (38%), NCEV-1530-11×Kissan-60 (35%), NCEV-1530-11×Ghuari-122 (34%) and NCEV-1530-11×Soan-3 (33%). Results are supporting the findings of Mubeen et al. (2015). They reported significant variability for disease incidence percentage among the maize genotypes due to presence of inoculum in wind or in field.

Area under disease progressive curve (AUDPC)

Mean values range from 10-402dsu. Maximum mean value for area under disease progressive curve was shown by genotype Soan-3 (402dsu), Ghuari (382dsu) and Kissan-60 (362dsu). Whereas minimum mean values were shown by genotype Karamat-Bar-25 (22dsu), NCEV-11 (22dsu) and SZP-13200 (10dsu) respectively. Crosses Kramat-Bar-25×Kissan-60 showed the AUDPC of 82dsu, Kramat-Bar-25×Ghuari-122 (162dsu), Kramat-

Bar-25×Soan-3 (322dsu), SZP-13200×Kissan-60 (62dsu), SZP-13200×Ghuari-122 (200dsu), SZP-13200×Soan-3 (82dsu), NCEV-1530-11×Kissan-60 (242dsu), NCEV-1530-11×Ghuari-122 (82dsu) and NCEV-1530-11×Soan-3 (282dsu). The results are similar to the finding of Ali et al. (2012). They assessed that greater the area under disease progressive curve more variety was the susceptible.

Reaction and scoring of disease

Under field conditions, the genotypes Kramat-Bar-25, SZP-13200 and NCEV-1530-11 displayed the disease severity of 5R, 2R, 5R and SZP-13200×Kissan-60 (15R) and showed resistance type reaction against Northern Corn Leaf Blight. While genotypes Soan-3, Kissan-60 and Ghuari-122 showed susceptible type response and reaction with rating values of 90S, 90S and 95S respectively. Crosses Kramat-Bar-25×Kissan-60, SZP-13200×Kissan-60, SZP-13200×Ghuari-122, and SZP-13200×Soan-3, NCEV-1530-11×Kissan-60, NCEV-1530-11×Ghuari-122 and NCEV-1530-11×Soan-3 showed moderately resistant (MR) reaction under field screening conditions. Whereas crosses Kramat-Bar-25×Ghuari-122 and Kramat-Bar-25×Soan-3 showed moderately susceptible (MS) type reaction (Table 3). Maha et al. (2015) detected the scale rating of leaf blight as resistant, susceptible and moderately resistant and moderately susceptible categories and made the crosses between highly resistant maize parents and noted that resistant genotypes yield the similar levels of resistance. On the other hand, when crosses were made with moderate resistant, the hybrids give good resistance to NCLB and concluded that classical breeding is one of the best methods for management and control of the NCLB disease.

Yield attributes

Mean values for plant height ranged from 101-200 cm (Table 4). Highly resistant genotypes Karamat-Bar-25 showed maximum plant height (200cm), SZP-13200 (195cm) and NCEV-1530-11(192cm), whereas highly susceptible genotypes Soan-3, Kissan-60 and Ghuari-122 had lowest plant height as 101cm, 107cm and 115 respectively. Mean value for ear height ranged from 14-20cm. Maximum ear height was showed by genotype Karamat-Bar-25 (20cm), SZP-13200 (19cm) and NCEV-1530-11(18cm) while minimum ear height was shown by genotypes Soan-3, Kissan-60 and Ghuari-122 as 15cm, 15cm and 14cm. Mean value for ear diameter

Table 3: Mean values and standard deviation for pathological traits of maize genotypes.

Sr. No.	Genotypes	LDI (%)	AUDPC	Scoring	Reaction
1	Karamat Bar-25 (Parent)	28±0.02	22±0.38	5	R
2	SZP-13200 (Parent)	25±0.01	10±0.13	2	R
3	NCEV-11 (Parent)	30±0.08	22±0.29	5	R
4	Kissan-60 (Parent)	64±0.02	362±0.03	90	S
5	Ghuari-122 (Parent)	75±0.07	382±0.73	90	S
6	Soan-3 (Parent)	77±0.01	402±0.21	95	S
7	Kramat-Bar-25×Kissan-60	54±0.09	82±0.38	20	MR
8	Kramat-Bar-25×Ghuari-122	41±0.04	162±0.48	40	MS
9	Kramat-Bar-25×Soan-3	64±0.03	322±0.28	70	MS
10	SZP-13200×Kissan-60	36±0.05	62±0.36	15	R
11	SZP-13200×Ghuari-122	50±0.08	200±0.35	50	MR
12	SZP-13200×Soan-3	38±0.02	82±0.78	20	MR
13	NCEV-1530-11×Kissan-60	35±0.09	242±0.31	60	MR
14	NCEV-1530-11×Ghuari-122	34±0.20	82±0.05	20	MR
15	NCEV-1530-11×Soan-3	33±0.36	282±0.02	70	MR
Statistics					
Total mean		45.60	181.06		
SE		4.45	36.507		
CV		78.343	700.800		

Table 4: Mean values and standard deviation for grain Yield and yield attributes of maize genotypes.

	Genotypes	PH	EH	ED	NKRPE	NKPR	1000 GW	GYPP	By
1	Karamat Bar-25 (Parent)	200±0.05	20±0.04	19±0.27	18±0.02	48±0.9	481.6±0.48	170.44±0.98	2806±0.02
2	SZP-13200 (Parent)	195±0.23	19±0.37	18±0.17	17±0.06	47±0.94	446.9±0.38	181.43±0.48	2995±0.39
3	NCEV-1530-11(Parent)	192±0.37	18±0.48	17±0.01	16±0.07	46±0.26	456.6±0.37	187.5±0.23	2915±0.48
4	Kissan-60 (Parent)	107±0.98	15±0.03	14±0.69	12±0.01	31±0.48	213.6±0.38	42.34±0.82	829±0.39
5	Ghuari-122 (Parent)	115±0.12	15±0.25	14±0.31	12±0.04	29±0.58	193.6±0.48	38.66±0.48	815±0.72
6	Soan-3 (Parent)	101±0.03	14±0.87	15±0.67	13±0.04	29±0.58	191.6±0.48	41.36±0.43	835±0.49
7	Kramat-Bar-25×Kissan-60	139±0.37	17±0.84	16±0.68	14±0.09	22±0.28	193.6±0.49	106.39±0.48	1817±0.49
8	Kramat-Bar-25×Ghuari-122	138±0.45	15±0.08	17±0.05	13±0.02	39±0.59	345.6±0.48	104.5±0.03	1810±0.36
9	Kramat-Bar-25×Soan-3	124±0.87	14±0.21	15±0.02	10±0.03	29±0.37	342.3±0.48	105.9±0.07	1820±0.03
10	SZP-13200×Kissan-60	171±0.37	16±0.87	16±0.38	14±0.05	45±0.37	335.6±0.47	111.88±0.03	1912±0.04
11	SZP-13200×Ghuari-122	165±0.45	17±0.03	16±0.28	15±0.38	38±0.31	325±0.34	110.04±0.32	1905±0.09
12	SZP-13200×Soan-3	176±0.09	16±0.47	16±0.19	14±0.04	36±0.22	336.3±0.05	111.4±0.11	1915±0.46
13	NCEV-1530-11×Kissan-60	135±0.04	18±0.38	17±0.38	15±0.03	45±0.63	310.9±0.43	114.94±0.07	1872±0.67
14	NCEV-1530-11×Ghuari-122	169±0.49	17±0.52	17±0.46	14±0.33	44±0.88	335.1±0.91	113.1±0.91	1865±0.58
15	NCEV-1530-11×Soan-3	150±0.38	16±0.13	19±0.48	16±0.09	46±0.09	325.1±0.01	114.45±0.44	1875±0.41

ranged from 14-19cm. Maximum ear diameter was showed by genotype Karamat-Bar-25 (19cm), SZP-13200 (18cm) and NCEV-1530-11(17cm) and minimum ear diameter was shown by genotypes Soan-3, Kissan-60 and Ghuari-122 as 14cm, 15cm and 15cm. Regarding number of kernel rows per ear,

mean values for the genotypes Karamat-Bar-25 was 18, SZP-13200 (17) and NCEV-1530-11(16) and was maximum as compare to the susceptible genotypes Soan-3 (12), Kissan-60(12) and Ghuari-122 (13) followed by number of kernel per row as also highest value shown by highly resistant genotypes as 48, 47

and 46 while lowest numbers of kernel was reported in susceptible genotypes. The data regarding to thousand grain weight revealed that the 1000-grain weight play significant role in increasing the yield, biological yield and other yield components. Maximum values for 1000-grain weight was noted for Karamat-Bar-25 (481.6g), SZP-13200 (446.9g) and NCEV-1530-11 (456.6g) and their grain yield and biological yield was also highest among all the genotypes as 181.43g, 170.44g, 187.54g and 2995g, 2915g and 2806g respectively. Similarly, Ali et al. (2011) evaluated the reproductive traits for yield and concluded that the 300 grain weight has a significant role in increasing the grain yield with relation to other yield related attributes. The current study supports the finding of their results.

Clusters analysis based on average linkage distance for patho-morphological traits

The patho-morphological traits of maize genotypes were classified in three main clusters, cluster I cluster II and cluster III (Figure 1). Cluster I is further divided into two sub clusters Ia and Ib, cluster II is further divide into two sub cluster IIa and IIb and cluster III is further divide into two sub cluster IIIa and IIIb. Sub cluster Ia contained genotypes Kissan-60 whereas sub cluster Ib is further sub divided into sub sub cluster which comprised the genotypes Ghuari-122 and Soan-3. These are the highly susceptible genotypes falls into same sub cluster and showed close genetic relation. Sub cluster IIa contained genotypes Kramat-Bar-25 and IIb consisted genotypes SZP-13200 and NCEV-1530-11. These are the highly susceptible genotypes and fall into same cluster and showing close genetic distance. First sub sub cluster of the sub cluster IIIa and IIIb contained the moderately susceptible Karamat-Bar-25×Kissan-60 and Karamat-Bar-25×Soan-3 which are apart from other sub sub cluster of sub cluster IIIa and IIIb which consisted genotypes which are moderately resistant (Karamat-Bar-25×Ghuari-122, NCEV-1530-11× Ghuari-122, SZP-13200 ×Kissan-60, SZP-13200× Soan-3, SZP-13200×Ghuari-122, NCEV-1530-11×Kissan-60 and NCEV-1530-11×Soan-3 and showing nearby genetic relation. Moderately susceptible genotypes indicated that they are of different genetic nature from other group of genotypes by falling into separate sub cluster. Results are match with the finding of Hasan (2015). They reported that resistant varieties falls in same cluster whereas susceptible ones into another separate cluster. While moderately resistant and susceptible

varieties and hybrids create separate cluster indicated close genetic characteristics.

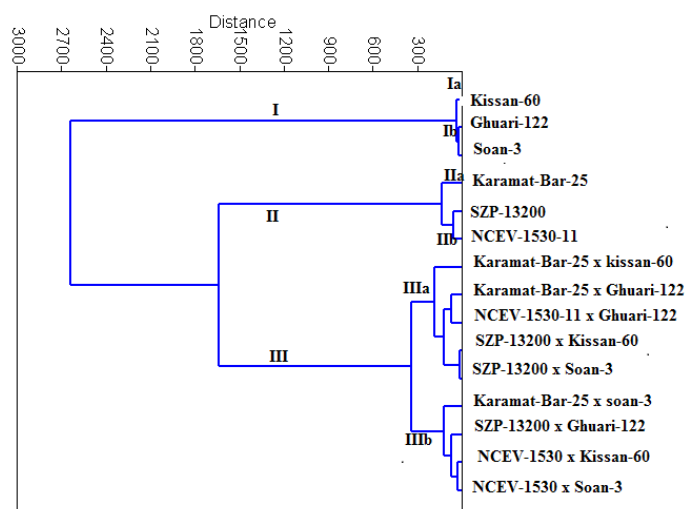


Figure 1: Dendrogram based on average linkage distance for patho-morphological traits in Maize genotypes.

Simple Correlation coefficients for Patho-morphological parameters

Simple correlation coefficient for patho-morphological traits is displayed in Table 5. Results showed that disease incidence was positively and highly significantly correlated with area under disease progressive curve while negatively and highly significantly correlated with plant height, ear height, ear diameter, number of kernel rows per ear, number of kernel per row, grain weight, grain yield and biological yield. Area under disease progressive curve was negatively and highly significantly correlated with plant height, ear height, number of kernel rows per ear, grain weight, grain yield and biological yield while negatively and significantly correlated with ear diameter and number of kernels per row.

Analysis of coefficient of correlation represented that plant height was positively and highly significantly correlated with ear height, ear diameter, number of kernel rows per ear, number of kernels per row, grain weight, grain yield and biological yield. While ear height was positively and highly significantly correlated with ear diameter, number of kernel rows per ear, number of kernel per row, grain weight, grain yield and biological yield. Ear diameter was positively and highly significantly correlated with number of kernel rows per ear, number of kernel per row, grain weight, grain yield and biological yield. Whereas number of kernel rows per ear was positively and highly significantly correlated number of kernel per row, grain weight, grain yield and biological yield.

Table 5: Simple correlation coefficients for patho-morphological parameters.

Correlation	DI	AUDPC	PH	EH	ED	NKRPE	NKPR	GW	GY	BY
DI	1									
AUDPC	.821**	1								
PH	-.863**	-.906**	1							
EH	-.764**	-.746**	.801**	1						
ED	-.854**	-.606*	.706**	.710**	1					
NKRPE	-.779**	-.660**	.783**	.887**	.839**	1				
NKPR	-.866**	-.549*	.733**	.653**	.779**	.739**	1			
GW	-.816**	-.712**	.863**	.682**	.729**	.654**	.803**	1		
GY	-.859**	-.839**	.897**	.803**	.773**	.747**	.702**	.914**	1	
YB	-.851**	-.848**	.905**	.802**	.768**	.744**	.688**	.917**	.998**	1

** : Correlation is significant at the 0.01 level (2-tailed); * : Correlation is significant at the 0.05 level (2-tailed).

Number of kernel per row was positively and highly significantly correlated with grain weight, grain yield and biological yield. Grain weight was positively and highly significantly correlated with grain yield and biological yield while grain yield was positively and significantly correlated with biological yield whereas biological yield was positively and highly significantly correlated with plant height, ear height, ear diameter, number of kernel rows per ear, number of kernel per row, grain weight, grain yield and biological yield while negatively and highly significantly correlated with disease incidence and area under disease progressive curve. The current results are similar to the results of [Raymundo \(1981\)](#) regarding the correlation between yield loss and area under disease progressive curve. They reported that number of kernel per ear, 500 grain weight is important component of yield loss and have positive and significant correlation with grain yield. When area under disease progressive curve will increase yield loss will also increase. Furthermore, recombination of maize heterotic groups into a single training set is a meaningful approach for improvement of Northern Corn Leaf Blight resistance.

Northern leaf blight (NLB) causes significant yield losses to crop maize in Pakistan. In the current study we assessed the efficacy of screening and selection of maize genotypes under NCLB stress for the yield and yield related traits. Selection and their utilization in breeding program meeting towards resistance improvement in genotypes against Northern Corn Blight stress. The screening from base population showed that Karamat-Bar-25, SZP-13200 and NCEV-1530-11 are highly resistant and Soan-3, Ghuari-122 and Kissan-60 are highly susceptible

toward NCLB and their selection for hybridization showed positive selection differential for plant height, ear length, ear diameter, number of kernel rows ear-1, number of kernels per row, 1000 grain weight, grain yield and biological yield whereas it has negative effect for NCLB severity, disease incidence and AUDPC, resulting a falling trend for these disease characteristics. Northern Corn Leaf Blight and grain yields of maize genotypes had significant relationships and present finding showed that the NCLB adversely affected the yield. In resistant genotypes yield is increases but in susceptible genotypes there a critical loss of grain yield and biological yield. The genotypes which are moderately resistant towards NCLB inoculation exhibiting the effectiveness of selection for improving Northern Corn Leaf Blight resistance. Yield components showed negative and inversely proportional relation with NCLB. As greater the disease incidence (DI) and diseased progressive curved area (AUDPC) lesser is the grain yield. Hybridization outcomes lead towards improvement of the yield and yield related component. Crosses between highly resistant and highly susceptible genotypes leads to the production of heterotic moderately resistant genotypes which are the key group for grain yield improvement within the germplasm. In the test material resistant and moderately resistant genetic material was greater in number as compare to the susceptible and moderately susceptible. Resistant and moderately resistant group results in enhancement of yield attributes. Similar work previously has been done by [Adipala et al., 1993](#); [Solomonovich et al., 1992](#); [Pataky, 1992](#); [Harlapur, 2005](#). They reported that losses in grain yield varied from 23.9 to 40.4 % with a mean of 33.3%. Another finding also supports

current study, Patil et al. (2000) studied that the yield depression was directly proportional to disease severity and grain losses ranged from 2.9-51.9 % and showed positive relation to Northern Corn leaf blight among maize genotypes. Similarly, Pandurangegowda (1991) reported early inoculation of 35 to 45 days after sowing may result in severe infection and leads considerable losses in grain yield. Similar finding was made by Hooker and Raymundo (1981) and reported that early inception of NCLB caused severe yield losses of 63 % when severity was 97% in maize. Selection on the basis of field screening is recommended for further improvement of NCLB resistance, yield and yield associated traits. The resistant, moderately resistant genotypes could be used as an improved germplasm which may plays a significant role in increasing maize production of North area of Rawalakot, Azad Kashmir as well as in Pakistan also.

Conclusions and Recommendations

The current research resulted in identification of 3 highly resistant (Kramat-Bar-25, SZP-13200 and NCEV-1530-11) and 3 highly susceptible genotypes (Soan-3, Ghuari-122, Kissan-60) genotypes and hybridization between these genotypes leads to the production of moderately resistant (Kramat-Bar-25×Kissan-60, SZP-13200× Kissan-60, SZP-13200× Ghuari-122, SZP-13200× Soan-3, NCEV-1530-11×Kissan-60, NCEV-1530-11×Ghuari-122, NCEV-1530-11×Soan-3) and moderately susceptible progenies (Kramat-Bar-25×Ghuari-122 and Kramat-Bar-25×Soan-3). In general, resistant and moderately resistant test materials were greater in number than susceptible and highly susceptible types. Resistant and moderately resistant genotypes showed greater yield and results in improvement of yield components as compare to susceptible ones. The new sources of NCLB resistance identified in the present study will helpful for their deployment in breeding program.

Acknowledgment

The author would like to thanks the National Agriculture Research Center (NARC) Islamabad and Cereal Crop Research Institute, PirSabaq, Nowshehra (KPK) for providing the Maize Seeds for the study.

Novelty Statement

Identification of new source of resistance against

Northern corn leaf blight (NCLB) will promote the yield improvement within the studied area.

Author's Contribution

Tahsin Razzaq: Conducted the research work and wrote the manuscript.

M. Fareed Khan: Developed research plan.

Shahid Iqbal Awan: Guided during writing and experiments.

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